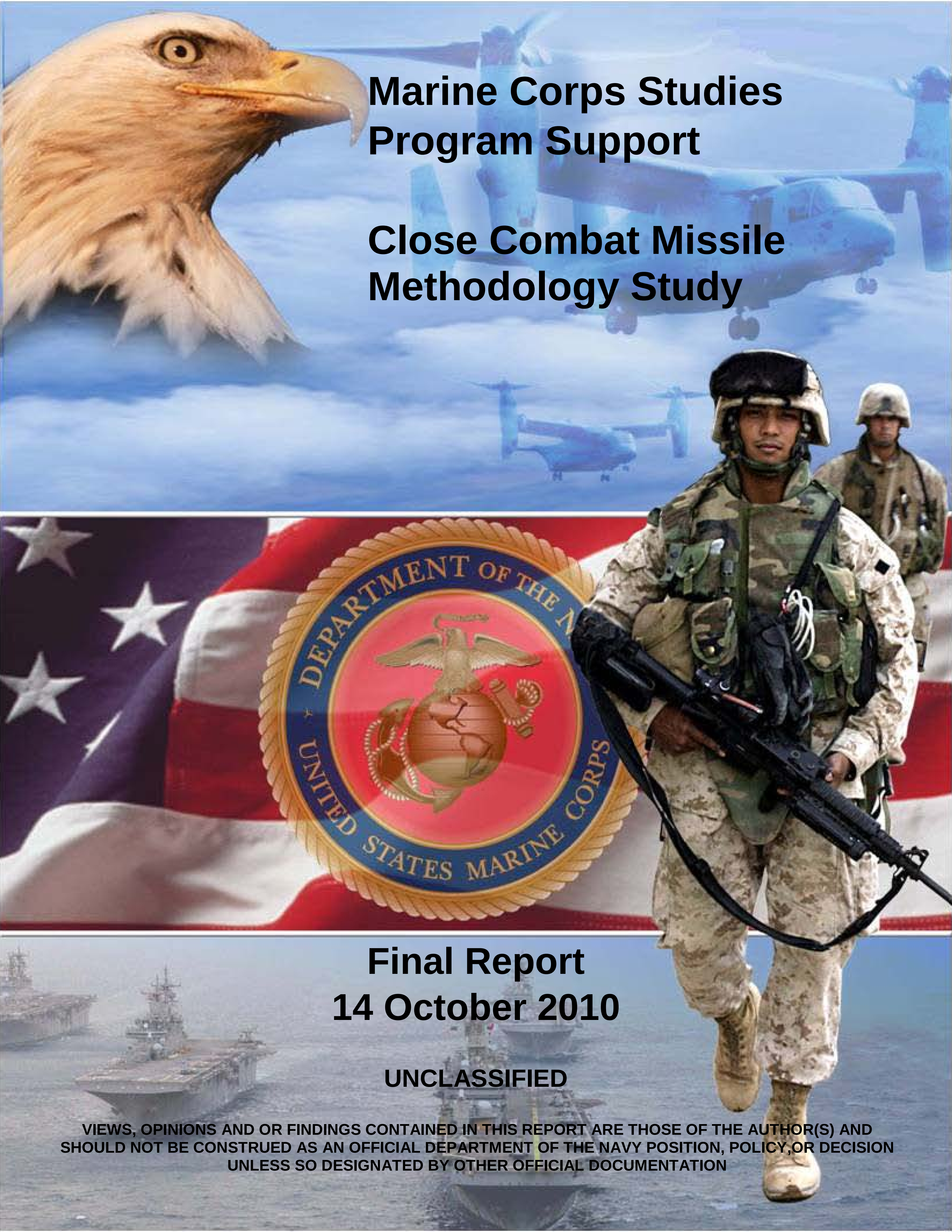

Marine Corps Studies Program Support

Close Combat Missile Methodology Study

Final Report
14 October 2010

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MARINE CORPS STUDIES PROGRAM SUPPORT

FINAL REPORT

Close Combat Missile Methodology Study

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Abstract

The objective of this study was to develop a methodology for evaluating different mixes of close combat missiles used in both state-on-state and hybrid warfare. Close combat missiles were defined as ground tactical line of sight missiles. The desired end product was a spreadsheet based multi-attribute decision value model. The study identified a number of missile characteristics, developed a decision hierarchy as the modeling framework, developed units of measures for those metrics, and implemented the conceptual model in an Excel™ Workbook. The Simple Multi-Attribute Rating Technique approach to weighting the characteristics was adopted. The results of interviews with Subject Matter Experts were captured in the spreadsheet model. A methodology for assessing mixes of missiles was developed and tested with the spreadsheet model.

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Executive Summary

The objective of this study is to develop a multi-attribute decision model to evaluate mixes of infantry anti-armor weapons for both state-on-state warfare (typified by a significant armored threat) and hybrid conflicts (typified by a negligible armored threat and the use of missiles in an anti-structure role). *Marine Corps Vision and Strategy 2025* recognizes that the Marine Corps must be prepared to fight traditional state-on-state conflicts, which are typified by a significant armored threat but not very likely, and hybrid warfare, which is more likely and typified by a negligible armored threat and the use of missiles in an anti-structure role.

Close combat missiles (CCMs) are defined, for the purposes of this study, as missiles used against terrestrial targets within line of sight by the Ground Combat Element (GCE). Traditionally, ground combat missiles have been used against armored targets in state-on-state warfare. However, in recent hybrid conflicts, they have been found to be useful as anti-structure weapons, used against caves, and other targets that traditional infantry weapons could not significantly affect or lacked the required range to engage. Traditional approaches to identifying optimum or suitable mixes of weapons have involved combat modeling. There are, as of this writing, no combat models capable of using CCMs against structures. This study was undertaken to develop a methodology that would consider both state-on-state and hybrid warfare for the purpose of evaluating the value of CCM mixes.

The decision model developed consists of a decision hierarchy (DH) for evaluating individual missiles and a missile mix methodology that incorporates individual missile DH values into an overall mix score based on the mix's collective value and capability.

The DH developed to evaluate individual missiles first decomposes individual missile value into sub-attributes until measurable sub-attributes are reached. Next, each attribute is weighted utilizing the Simple Multi-Attribute Rating Technique (SMART) method. In the first step of the SMART method, each set of sibling attributes (attributes having the same parent attribute) of the DH is considered. Within each set of sibling attributes, the least influential sibling attribute is determined and assigned a SMART score of ten. Next, the SMART scores of the other sibling attributes relative to the least influential sibling attribute are determined. Then local weights for each sibling attribute are calculated by dividing each attribute's SMART score by the sum of the SMART scores of each sibling attribute. After this process is repeated on each level of the DH for each set of sibling attributes, the local weights of the bottom-most attributes are multiplied up the branches of the DH to determine the overall weights of each attribute. The Study Team implemented the SMART method by assigning best guess SMART scores developed from the results of SME interviews.

The Study Team developed recommended units of measure for each attribute. Certain attributes were recommended to be measured categorically in anticipation that subsequent data would not be readily available. Some pre-defined categories were utilized for multiple attributes (Yes/No, None/Medium/High/Low, etc.) while other attributes required customized categorical measures. Attributes for which categorical scoring was inappropriate were recommended to be measured as continuous variables. For these attributes, it was determined that scores would be calculated using linear interpolation between a threshold and objective value. Thus, for each attribute to be

measured as a continuous variable, three values need to be specified: threshold, threshold score, and objective. The threshold is the minimum value considered acceptable for an attribute and the threshold score (which can be non-zero) is the score earned by a CCM that exactly achieves the threshold for that attribute. The objective is the minimum value for which an attribute can achieve the maximum score. Attributes with values below the threshold achieve a score of zero. Attributes with values in between the threshold and objective are scored linearly between the threshold score and 100% (which is always the maximum score for an attribute) while attributes with values equal to the objective or higher receive a score of 100%. After each attribute is weighted and scored, the weights and scores for each attribute are multiplied and aggregated (summed) up the branches of the hierarchy to calculate the overall DH score of the individual missile. The Study Team provided best guess scoring parameters for the missiles of interest based off SME interviews and outside research.

After each individual missile receives a DH score, the mix methodology can then be applied to calculate a mix score based upon the mix's value and capability. First, the quantity and type of missiles in the mix under consideration must be constrained in some manner such as by operational or force structure restrictions. Then the quantity of each missile type and the DH score for each missile are combined to establish the overall value of the mix. Next, the task goals to be accomplished by the missile mix are established. Each task goal is then assessed for its importance and its likelihood in both state-on-state and hybrid warfare. Then, for each missile, the probability of achieving each task goal is determined. The importance and likelihood SMART scores combined with missile quantities and the probabilities of success of the missiles against the task goals are used to calculate the overall capability of the mix. Then, the relative weighting of value to capability is determined and the mix's overall score is computed from the value and capability scores. Scores of multiple mixes are compared by giving the mix with the highest score a normalized score of 100% with all other mix scores calculated relative to it. The Study Team provided a preliminary list of task goals along with best guess probabilities of success for missiles against task goals.

1. INTRODUCTION

1.1. Objective

The objective of this study is to develop a multi-attribute decision model to evaluate mixes of infantry anti-armor weapons for both state-on-state warfare (typified by a significant armored threat) and hybrid conflicts (typified by a negligible armored threat and the use of missiles in an anti-structure role).

1.2. Background

According to *Marine Corps Vision and Strategy 2025*:

> ”Hybrid conflicts are assessed as the most likely form of conflict facing the United States. Few states, if any, are capable of matching America’s overwhelming conventional military combat power. Because of our conventional superiority, adversaries will seek more indirect forms of conflict... Discrimination in the application of violence will be consistent with the threat, and minimizing collateral damage will be an important consideration.”

Nevertheless, *Marine Corps Vision and Strategy 2025* also states:

> “While the threat of state-on-state warfare featuring the destructive capabilities of major powers has declined, it remains a distinct possibility. It must still be regarded as the most dangerous threat to the Nation.”

Anti-armor systems within the Marine Corps have become an area of high concern given the threat of state-on-state warfare. Anti-armor systems, however, can be valuable assets in the irregular environment of hybrid conflicts, even when there is no appreciable armored threat.

The last USMC Anti-Armor Mix Study was conducted in 1999. That Study was based on a state-on-state warfare strategy for our nation to win two major regional conflicts (MRCs) nearly simultaneously. Whereas the study methodology was appropriate for state-on-state warfare, it was inappropriate for hybrid conflicts. Today’s Marines must operate proficiently in both state-on-state warfare and hybrid conflicts. Likewise, weapons system evaluations have to include capabilities suitable for both state-on-state warfare and hybrid conflicts.

In addition, since the time of the Anti-Armor Mix Study, new systems and capabilities have been introduced into the Marine Air-Ground Task Forces (MAGTFs) which could have a potential effect on operational missions and systems distributions. This study addresses both the need for a comprehensive methodology for evaluating alternative mixes used in both state-on-state and hybrid warfare, and the introduction of new capabilities into the MAGTF.

1.3. Study Scope

The scope of this study is limited to the development of the methodology and the construction of a software model that reproduces that methodology. The resulting model is suitable for evaluating mixes of close combat weapons to include all current

and projected Marine Corps systems whose attributes are well known. No costs of any kind were considered. However, weapon and ammunition quantities, capability, utility, lethality, and other such performance parameters were the primary considerations. The Study Team created several test missile mixes to ensure that the methodology was valid and that the software worked appropriately.

The definition of CMMS was provided by the Government, but was generally understood to be those missiles that are issued to the GCE for use against targets to which there is a line of sight from the gunner to the target, and the target is a terrestrial object, rather than an aircraft.

1.4. General Approach

The technical effort for this study was divided into five activities:

1. Identify candidate multi-attribute utility methodologies,
2. Determine what attributes should be included in the analysis
3. Establish a means for creating a measurable score for each attribute
4. Identify methods to combine scores of individual missile systems to evaluate a mix of missile systems, and
5. Construct a software product that automates the calculation of the scores, and provides a means of identifying the contribution of each component of the score into the overarching score.

At various points throughout the study, the Study Team, which included Government representatives, made decisions about which methodologies to use. No methodology is completely without flaws or biases. However, some seemed more suited to the problem at hand than others.

1.5. Other Considerations

Traditionally, weapons mix studies have been conducted using combat models and approved scenarios. Although the Marine Corps will retain its traditional state-on-state capability, it must also consider its more likely role in hybrid warfare. Specifically, close combat missiles have been used in built-up terrain to kill or suppress the occupants of a building, destroy parts of a building, or to create a breach in the wall of a building or compound so that Marines could enter it. Other uses include neutralizing sniper positions beyond small arms range and preventing the installation of an Improvised Explosive Device (IED). Currently, no validated combat models exist that consider missiles used in this manner.

2. LITERATURE REVIEW

The first step in this methodology development effort was to perform a literature review. This review was conducted largely through internet searches, identifying various articles and web sites that provided useful and relevant information. In addition, Marine Corps Center for Lessons Learned (MCCLL) entries, various field manuals, and technical descriptions of missiles were also included in the review. The following sections identify the information that was located and the recommendations and decision rationale for each.

2.1. Multi-Attribute Decision Analysis

A literature review was conducted on multi-attribute decision analysis to identify proper and effective procedures for creating a multi-attribute decision model. Additionally, information was gathered on the process of developing a DH for the purpose of implementing the decision analysis. A summary of the findings is located in Appendix C.

2.2. Multi-Attribute Utility Analysis Methodologies

A literature search was conducted to identify candidate multi-attribute utility methodologies. A brief description of each and an assessment of its suitability to this effort is provided here, while a more detailed description can be found in Appendix D. The methodologies identified in this search were:

1. The Analytic Hierarchy Process (AHP)
2. Simple Multi-Attribute Rating Technique (SMART)
3. Strengths, Weaknesses, Opportunities and Threats (SWOT)
4. Decision Expert (DEX)

After some discussion, the Government selected SMART as the multi-attribute decision weighting methodology for calculating the weights of the DH. The SMART technique consists of several steps. The first step requires that the user determine the least influential attribute of each level of the DH, and assign that attribute a score of ten. Next, the scores of the remaining attributes of the same level are assigned relative to the least influential attribute. All scores are then apportioned into weights by dividing each score by the sum of the scores of all of the attributes of that level of the DH. The apportionment of the SMART scores ensures that the sum of the weights of each level is one.

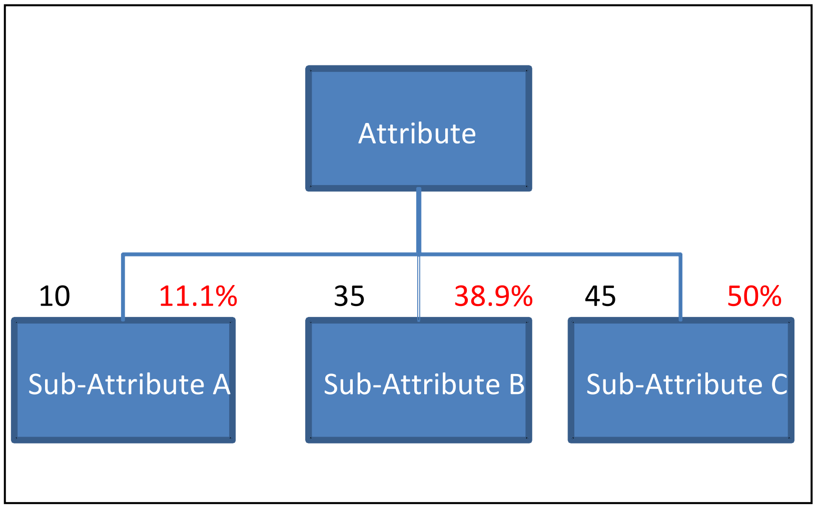

Figure 2-1. SMART Example

For example, Figure 2-1 shows an attribute within a DH diagram. The three sub-attributes have been reviewed by the user who determined Sub-Attribute A to be the least important, and assigned it a score of ten (shown in black numbers). Sub-Attribute B was judged to be between three and four times as important as Sub-Attribute A and was assigned a score of 35. Sub-Attribute C was judged to be more important than Sub-Attribute B and received a score of 45. The sub-attributes were then weighted by apportioning the SMART scores. The weights are shown in red. With this approach, the SME creating the weights does not have to worry that his weights do not add up to one. Because the Study Team decided to build a comprehensive DH to avoid inadvertently omitting an attribute, the SMART methodology was slightly expanded upon to allow the SME to assign an attribute a score of zero if the attribute it is desired to omit the attribute from consideration within the DH.

2.3. CCM Attributes

A literature search was conducted to identify CCM attributes to consider for inclusion in the model and for weighting into an overall value for each missile. The results of the literature search and the list of attributes that were selected for inclusion in the decision model can be found in Chapter 3 of this report.

2.4. Tactics Techniques and Procedures

The Government provided a few lessons learned from Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) on the use of CCMs in hybrid warfare. Key points from these documents include:

- The use of a high explosive (HE) warhead to create a breach in a wall, with a second shot through the breach using a thermobaric warhead (NE or Novel Explosive) to kill the occupants of a building.
- Use of missiles against infantry positions that were out of range of Marine rifle or automatic weapons fire or that were well protected by terrain.

3. CCM ATTRIBUTES

3.1. Introduction

This section of the report describes the list of measurable CCM attributes that are included in the DH. The attributes were compiled using the information available regarding CCMs currently deployed by the USMC. These missiles are:

- BGM-71E Tube launched, Optically tracked, Wire guided (TOW) 2A
- BGM-71F TOW-2B
- BGM-71H TOW-2 Bunker Buster (BB)
- FGM-148 Javelin
- Mk.153 mod 0 Shoulder-launched Multi-purpose Assault Weapon (SMAW) – Mk.3 High Explosive Dual Purpose (HEDP)
- Mk.153 SMAW Mk.6 High Explosive Anti-Armor (AA)
- Mk.153 SMAW Mk.80 Novel Explosive (NE)
- SMAW-II
- M-136 Anti-Tank (AT)-4
- M72 Light Anti-tank Weapon (LAW)

The attributes were grouped into three general categories:

1. Utility,
2. Logistical, and
3. Other.

Figure 3-1. A High Mobility Multipurpose Wheeled Vehicle (HMMWV) With TOW-2B is a Single System

A CCM is considered a complete weapon system that includes a missile, launcher, and platform. A CCM may also take into account the type of warhead as preferred by the user.

It was recognized that some attributes contribute to more than one of the three functional areas. In that case, the corresponding attribute was placed within the functional area that the Study Team deemed more influential to the overall value of a CCM. Table 3-1 lists the measurable attributes selected for inclusion in the DH grouped by type, and listed in alphabetical order.

3.2. Selected Attributes

The attributes shown in Table 3-1 are the measurable attributes of the DH that were selected for consideration to determine the overall value of a CCM.

Table 3-1. Measurable Attributes Selected for Consideration

Utility	
All Terrain Mobility	Minimum Safe Distance
Armor Protection Direct Fire	Minimum Temperature
Armor Protection Indirect Fire	Noise Signature
Back Blast Angle	Passive IR Sight
Back Blast Distance	Platform Top Speed
Capture Prevention	Probability of Success
Collateral Damage	Recognition Range
Countermeasure Susceptibility	Restricted Rules of Engagement
Designated (Guidance)	Self Guided
Detection Range	Set Up Time
Fire and Forget	Smoke Signature
Fire From Enclosure	Tear Down Time
Fire When Prone	Thermal Sight
Flash Signature	Time of Flight to Max Range
Flight Path Restrictions	Time to Reload After Firing Basic Load
Gunner Guided	Time Until First Shot
Horizontal Traverse	Time Until Second Shot
Identification Range	Use in Dust/Sand
Maximum Depression	Use in Fog
Maximum Effective Range	Use in Other Obscurant
Maximum Elevation	Use in Rain/Snow
Maximum Temperature	Use in Smoke
Minimum Effective Range	
Logistics	**Other**
Battery Life (Optics)	Friendly Casualties per 1000 per Year
Crew Size	Initial Training
Launcher/Platform Volume	Negligent Discharges per 1000 per
Launcher/Platform Weight	Probability of Hang Fire
Mean Time To Failure (MTBF)	Probability of Misfire
Mean Time To Repair (MTTR)	Sustainment Training
Missile Volume	
Missile Weight	
Number of Shots in Basic Load	
Operational Availability	
Preventative Maintenance	
Shelf Life	

3.2.1. Utility Attributes

The following set of attributes predominately describes the utility of a CCM.

3.2.1.1. All Terrain Mobility

All terrain mobility is captured with a yes or no response. Mobility for the same missile may vary based on the launcher platform (i.e., a missile mounted onto a HMMWV may not possess all-terrain mobility but a shoulder-mount version of the same missile does possess this mobility as it can be transported anywhere on foot).

3.2.1.2. Armor Protection – Direct Fire

Armor protection refers primarily to the platform from which the missile is fired. A vehicle mounted missile launcher will provide more armor protection than a shoulder fired missile system. Direct fire armor protection refers to the amount of front protection.

3.2.1.3. Armor Protection – Indirect Fire

Indirect fire armor protection refers to the amount of overhead protection.

3.2.1.4. Back Blast Angle

The back blast area of a missile is the cone-shaped area to the rear of the missile launcher that is dangerous to personnel due to the blast of missile debris and overpressure that occurs upon missile launch. The back blast angle measures the angle extending from the rear of the weapon from which the back blast area originates.

3.2.1.5. Back Blast Distance

The back blast distance measures the distance covered by the back blast area extending from the rear of the weapon.

3.2.1.6. Capture Prevention

To prevent CCM systems from being captured and used by the enemy, some systems may have devices that allow for capture prevention of one form or another.

3.2.1.7. Collateral Damage

Collateral damage is an important factor to consider in hybrid warfare in which targets are often structures in urban areas. The ability to effectively combat the enemy in an urban environment without the risk of unnecessary civilian deaths or infrastructure damage is crucial in such urban environments, and may not even be a consideration in state-on-state warfare.

3.2.1.8. Countermeasure Susceptibility

Some fire and forget missiles may be susceptible to counter measures of various kinds that spoof the sensor or defeat the warhead. Warhead effectiveness also may be reduced by reactive armor appliqués.

3.2.1.9. Designated (Guidance)

This guidance system depends on a laser or other type of designation mechanism that the missile homes in on.

3.2.1.10. Fire and Forget

The term fire and forget is used to categorize any missile in which the operator is not required to guide the missile beyond the initial launch or that can hit its target without being in direct line-of-sight of the target.

3.2.1.11. Fire From Enclosure

During urban operations, which are likely in hybrid warfare, the ability to fire a missile from an enclosure may be desirable.

3.2.1.12. Fire When Prone

The ability to fire a missile when in the prone position may be advantageous during specific operations.

3.2.1.13. Flash Signature

The amount and type of launch signature emitted from a launched missile is important as the amount of flash, noise, or smoke can reveal the location of the missile's origin and thus the location of the operator. The flash signature of a missile is the amount of flash emitted when the missile is fired.

3.2.1.14. Flight Path Restrictions

Because of the guidance system or the flight profile, some missiles may not be able to be fired. Flight path restrictions may include electrical wires, metallic objects between the gunner and the shooter, or overhead restrictions.

3.2.1.15. Gunner Guided

A gunner guided missile is one in which the operator must steer the missile to the target after firing. Guidance type has a direct impact on the accuracy of the missile and thus the probability of hit.

3.2.1.16. Horizontal Traverse

The field of fire of a missile is subdivided into three categories: horizontal traverse, maximum depression, and maximum elevation. Horizontal traverse measures the extent to which the missile can be rotated in a horizontal plane.

3.2.1.17. Identification Range

As mentioned previously, the range of a missile is an important consideration, but is governed, in part, by the ability to identify targets. Identification range is the distance at which a target can be positively identified using the system's optics, if any.

3.2.1.18. Maximum Depression

Maximum depression is the steepest angle at which the missile can be fired downward in a vertical plane.

3.2.1.19. Maximum Effective Range

Maximum effective range is the maximum effective distance that the system can be fired.

3.2.1.20. Maximum Elevation

Maximum elevation is the steepest angle at which the missile can be fired upward in a vertical plane.

3.2.1.21. Maximum Temperature

This is the maximum temperature at which the CCM can be used effectively.

3.2.1.22. Minimum Effective Range

Some CCM systems require that they fly a minimum distance before all onboard systems begin to function properly and thus effectively.

3.2.1.23. Minimum Safe Distance

The minimum safe distance refers to the minimum distance that a dismounted Marine can be located from the warhead's explosion to remain safe from its effects.

3.2.1.24. Minimum Temperature

This is the minimum temperature at which the CCM can be used effectively.

3.2.1.25. Noise Signature

Noise signature is the amount of noise created when the missile is fired.

3.2.1.26. Passive Infrared (IR) Sight

Passive IR sights detect the infrared emissions of an object if it is different from the background.

3.2.1.27. Platform Top Speed

Platform Top Speed is the speed of the platform upon which the CCM is mounted. For man portable or shoulder fired systems, this is the speed of a Marine on foot.

3.2.1.28. Probability of Success

Lethality is typically considered to be the probability of hit and probability of kill given hit as a function of range. For this study, range is considered to be independent of lethality. Since the warheads in question do not depend upon kinetic energy to be effective, range is not a factor in probability of kill given hit. Probability of hit is a derivative of the guidance system, time of flight and susceptibility to countermeasures. In hybrid warfare, the use of CCM may include targets for which the desired objective cannot be classified as killing the target. Therefore, the model methodology defines lethality as the ability to achieve a desired mission objective using the CCM. For example, in state-on-state warfare, the mission objective may be to stop a moving tank, while in hybrid warfare, the mission objective may be to create a Marine sized breach in a brick wall. Thus, lethality, which connotes killing something, was dropped in favor of probability of success. Multiple targets are included in the methodology to provide a spectrum of missile uses. To capture capability of a mix, it is important that the methodology define a set of mission objectives that represent the spectrum of state-on-state or hybrid warfare. A specific mission objective may appear in both state-on-state and hybrid warfare branches, but may be assigned different weights in each branch.

3.2.1.29. Recognition Range

The recognition range is the range at which a missile can recognize a target. Note that the recognition range may not necessarily lie within the maximum effective range.

3.2.1.30. Restricted Rules of Engagement

Some CCM types may be restricted from being used in all situations. These restrictions may include the possibility of collateral damage, a shortage of a particular type of missile in the deployment area, or the cost of the missile relative to other means for achieving a mission objective.

3.2.1.31. Self Guided

Some CCMs are able to guide themselves to a target, once locked on to that target.

3.2.1.32. Set Up Time

Set up time is the time between the launcher and platform arriving at a firing position and the point in time that the missile is ready to be fired.

3.2.1.33. Smoke Signature

Smoke signature is the amount of smoke emitted from the blast created when a missile is fired.

3.2.1.34. Tear Down Time

Tear down time is the time between the operator making the decision to move and the platform’s ability to begin relocation to another site.

3.2.1.35. Thermal Sight

A thermal sight is able to distinguish differences in heat signature between a potential target and the background. When objects and their background are nearly the same temperature, a thermal sight will have difficulty detecting the object.

3.2.1.36. Time of Flight to Max Range

The speed of the missile may vary during its flight. This measure is the time it takes the missile to get to its maximum range.

3.2.1.37. Time to Reload After Firing Basic Load

Once the basic load of the platform and launcher is expended, this measures how long it takes to reload the platform and launcher with a new basic load, assuming the missiles are readily available. The time to transport the missiles to the platform and launcher is not considered.

3.2.1.38. Time until First Shot

The time until the first shot takes into account the amount of time needed for target location and identification, and then actually triggering the missile. This may be as simple as pointing and pulling the trigger or may require electronics to lock on to a target resulting in a longer timeframe.

3.2.1.39. Time until Second Shot

After launching the first missile, this is the time it takes to reload the launcher, reacquire the target, and fire a second shot. A gunner-guided missile requires the gunner to guide

the missile to its target before reloading can begin. It assumes that a second missile is available.

3.2.1.40. Use in Dust/Sand

The ability of a missile to be used in certain obscurants is important when taking into consideration the diverse operating environment. A missile system that operates effectively in dust and sand may be desirable.

3.2.1.41. Use in Fog

A missile system that operates effectively in fog may be desirable.

3.2.1.42. Use in Other Obscurant(s)

A missile system that operates effectively in other obscurant(s) may be desirable.

3.2.1.43. Use in Rain/Snow

A missile system that operates effectively in rain, snow, and other precipitation may be desirable.

3.2.1.44. Use in Smoke

Some night vision capabilities provide an ability to see through obscurants, whether they are artificial, such as blowing sand, or manmade, such as a deliberate smoke screen.

3.2.2. Logistical Attributes

The following characteristics are related to logistical considerations.

3.2.2.1. Battery Life (Optics)

If the optics system requires batteries, battery life is the length of time that the batteries stay charged.

3.2.2.2. Crew Size

Crew size is the number of Marines required to man the system. For vehicle mounted systems, this includes the vehicle crew.

3.2.2.3. Launcher/Platform Volume

The cube or volume of the system may be important for shipboard stowage requirements or for transport in a vehicle.

3.2.2.4. Launcher/Platform Weight

The weight of the system affects strategic and operational mobility, and may affect tactical mobility.

3.2.2.5. Mean Time Between Failures (MTBF)

Mean Time to Failure is a measure of the system’s reliability during protracted use. For vehicle mounted systems, it also includes the failure of the vehicle.

3.2.2.6. Mean Time to Repair (MTTR)

Once a system failure has been detected, MTTR is a measure of the time it takes to return the system to operational working order.

3.2.2.7. Missile Volume

Missile volume is important for storing the basic load, particularly in vehicle mounted systems.

3.2.2.8. Missile Weight

The weight of the missile impacts the number of missiles that can be carried by an individual or stowed on a vehicle.

3.2.2.9. Number of Shots in Basic Load

The number of shots in the basic load for the CCM is considered as appropriate.

3.2.2.10. Operational Availability

This is a measure of the reliability of the system. It is typically the number of fielded and working systems divided by the total number of fielded systems.

3.2.2.11. Preventative Maintenance

Preventive maintenance is a measure of the time required to routinely service the system to ensure that it is in good working order.

3.2.2.12. Shelf Life

Because rocket motors, electronics, and other components may begin to fail over time, the shelf life of a CCM is an important consideration.

3.2.3. Other Attributes

The following characteristics, although contributing to both combat capability and logistical considerations, have been placed in a category of their own.

3.2.3.1. Friendly Casualties per 1000 per Year

With safety as an important consideration to any missile system, the measure of friendly casualties per 1000 per year provides some insight as to the relative safety of a missile system.

3.2.3.2. Initial Training

Initial training refers to the amount of training time required by the operator(s) of a missile system to become proficient enough (as dictated by some standard) to sufficiently operate the missile system. Training may include time spent in the classroom, at a field or range, or with a simulator.

3.2.3.3. Negligent Discharges per 1000 per Year

The measure of negligent discharges per 1000 per year provides some insight as to the relative safety of a missile system.

3.2.3.4. Probability of Hang Fire

The probability of hang fire measures the probability of a delay between the time when a missile system is triggered and the time the missile leaves the launcher system.

3.2.3.5. Probability of Misfire

The probability of misfire measures the probability that the missile is fired unintentionally.

3.2.3.6. Sustainment Training

Sustainment training is the amount of time a CCM crew must train with a system in a given time period (such as per year) to remain proficient in its use.

3.3. Default Score Type and Units of Measure for Selected Attributes

Upon inspection of the list of selected attributes, the Study Team determined that the scoring method utilized would depend on the units of measure deemed appropriate for an attribute. The Study Team identified six different score types and subsequent scoring methods with which to score attributes.

3.3.1. Threshold Score Type

A Threshold score type is suitable for attributes that should be measured as continuous variables. For these attributes, scores are calculated using linear interpolation between a threshold and objective value. Thus, for attributes with a Threshold score type, three values needed to be specified: threshold, threshold score, and objective. The threshold is the minimum value considered acceptable for an attribute and the threshold score (which can be non-zero) is the score earned by a CCM that exactly achieves the threshold for that attribute. The objective is the minimum value for which an attribute can achieve the maximum score. Attributes with values below the threshold achieve a score of zero. Attributes with values in between the threshold and objective are scored linearly between the threshold score and 100% (which is always the maximum score for an attribute) while attributes with values equal to the objective or higher receive a score of 100%. Figure 3-2 illustrates the linear scoring method for attributes with a Threshold score type.

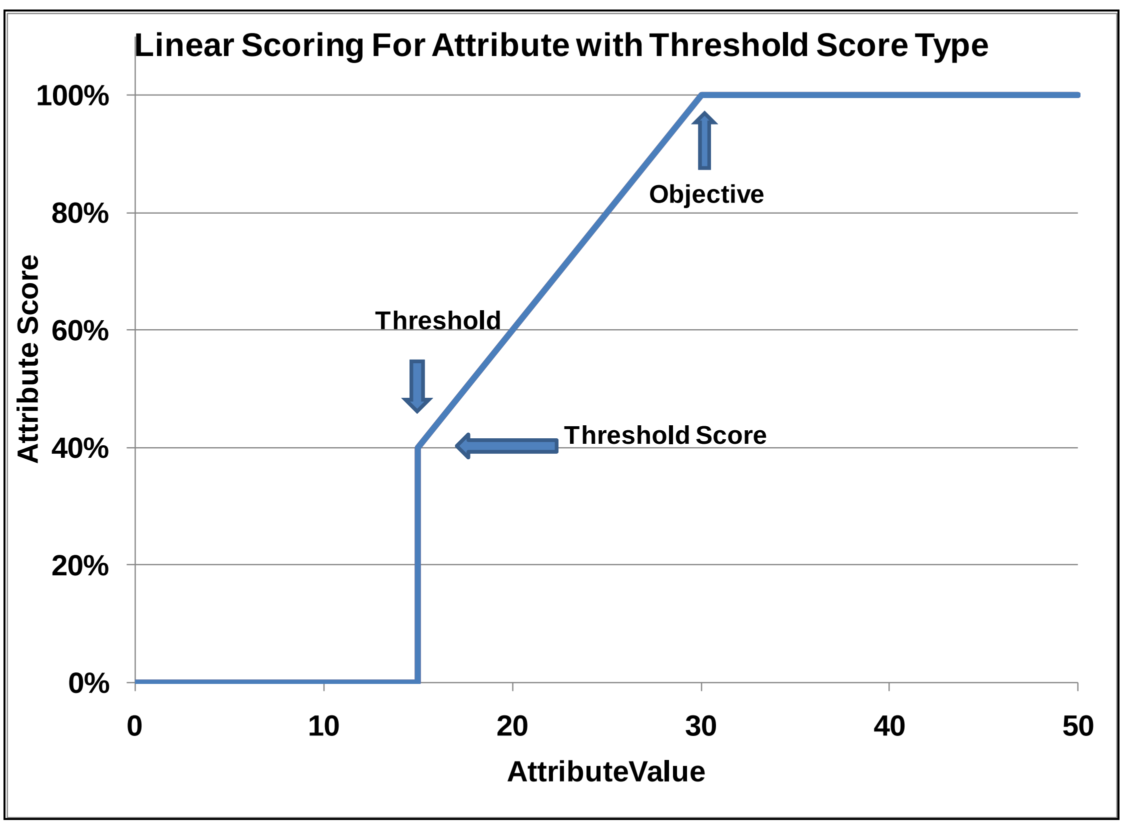

Figure 3-2. Linear Scoring Method for Attributes with a Threshold Score Type

3.3.2. Yes/No and No/Yes Score Type

A Yes/No score type is suitable for attributes in which “Yes” is the desired state. Under this score type, an attribute with a characterization of “Yes” will receive the maximum score of 100% while an attribute with a characterization of “No” will receive a score of zero.

A No/Yes score type is suitable for attributes in which “No” is the desired state. Under this score type, an attribute with a characterization of “No” will receive the maximum score of 100% while an attribute with a characterization of “Yes” will receive a score of zero.

3.3.3. None/Low/Medium/High and High/Medium/Low/None Score Type

A None/Low/Medium/High score type is suitable for attributes that are qualitative in nature or for which quantitative data is not available. Under the None/Low/Medium/High score type, “None” is the desired state receiving the maximum score of 100%. An attribute with a characterization of “Low” will receive a score of 66.66% and an attribute with a characterization of “Medium” will receive a score of 33.33%. A “High” characterization will result in a score of zero for the attribute.

A High/Medium/Low/None score type is suitable for attributes that are qualitative in nature or for which quantitative data is not available. Under the High/Medium/Low/None score type, “High” is the desired state receiving the maximum score of 100%. An attribute with a characterization of “Medium” will receive a score of 66.66% and an attribute with a characterization of “Low” will receive a score of 33.33%. A “None” characterization will result in a score of zero for the attribute.

3.3.4. Categorical Score Type

A Categorical score type is suitable for attributes that cannot be scored as continuous variables due to a lack of readily available quantitative data or the nature of the attribute values and for which the Yes/No, No/Yes, None/Low/Medium/High, and High/Medium/Low/None score types are not appropriate. Additionally, the Categorical score type is ideal for attributes that A categorical score type allows a SME to determine the appropriate number of value levels for the attribute and then assign corresponding scores for each level. .

Table 3-2 shows the default score type and units of measure chosen by the Study Team for utility attributes.

Table 3-2. Default Score Type and Units of Measure for Utility Attributes

Utility	Score Type	Unit of Measure
All Terrain Mobility	Yes/No	Yes/No
Armor Protection Direct Fire	Threshold	Caliber of Armor Protection
Armor Protection Indirect Fire	Threshold	Caliber of Armor Protection
Back Blast Angle	Threshold	Degrees
Back Blast Distance	Threshold	Meters
Capture Prevention	High/Medium/Low/None	None/Low/Medium/High
Collateral Damage	None/Low/Medium/High	None/Low/Medium/High
Countermeasure Susceptibility	None/Low/Medium/High	None/Low/Medium/High
Designated (Guidance)	Yes/No	Yes/No
Detection Range	Threshold	Meters
Fire and Forget	Yes/No	Yes/No
Fire From Enclosure	Categorical	None/Small/Medium/Large
Fire When Prone	Yes/No	Yes/No
Flash Signature	None/Low/Medium/High	None/Low/Medium/High
Flight Path Restrictions	No/Yes	Yes/No
Gunner Guided	No/Yes	Yes/No
Horizontal Traverse	Threshold	Degrees
Identification Range	Threshold	Meters
Maximum Depression	Threshold	Degrees
Maximum Effective Range	Threshold	Meters
Maximum Elevation	Threshold	Degrees
Maximum Temperature	Threshold	Degrees Fahrenheit
Minimum Effective Range	Threshold	Meters
Minimum Safe Distance	Threshold	Meters
Minimum Temperature	Threshold	Degrees Fahrenheit
Noise Signature	None/Low/Medium/High	None/Low/Medium/High
Passive IR Sight	Yes/No	Yes/No
Platform Top Speed	Threshold	Miles per Hour
Probability of Success	Threshold	Probability
Recognition Range	Threshold	Meters
Restricted Rules of Engagement	No/Yes	Yes/No
Self Guided	Yes/No	Yes/No
Set Up Time	Threshold	Minutes
Smoke Signature	None/Low/Medium/High	None/Low/Medium/High
Tear Down Time	Threshold	Minutes
Thermal Sight	Yes/No	Yes/No
Time of Flight to Max Range	Threshold	Seconds
Time to Reload After Firing Basic Load	Threshold	Minutes
Time Until First Shot	Threshold	Seconds
Time Until Second Shot	Threshold	Seconds
Use in Dust/Sand	Yes/No	Yes/No
Use in Fog	Yes/No	Yes/No
Use in Other Obscurant	Yes/No	Yes/No
Use in Rain/Snow	Yes/No	Yes/No
Use in Smoke	Yes/No	Yes/No

3.3.5. Utility Attributes

3.3.5.1. All Terrain Mobility

All terrain mobility is measured with a yes or no response. A yes characterization indicates that the system is capable of all terrain mobility and a no characterization indicates that the system does not possess all terrain capability.

3.3.5.2. Armor Protection – Direct Fire

Armor protection against direct fire is measured in terms of the highest caliber against which the armor provides forward protection.

3.3.5.3. Armor Protection – Indirect Fire

Armor protection against indirect fire is measured in terms of the highest caliber against which the armor provides overhead protection.

3.3.5.4. Back Blast Angle

The back blast angle is measured in degrees.

3.3.5.5. Back Blast Distance

The back blast distance is measured in meters.

3.3.5.6. Capture Prevention

As it is difficult to measure capture prevention quantitatively, capture prevention is measured on a qualitative scale of none (meaning there is no method of capture prevention for the missile), low, medium, or high.

3.3.5.7. Collateral Damage

As collateral damage cannot be easily described quantitatively, the extent of collateral damage will be measured qualitatively on a scale of none, low, medium, or high.

3.3.5.8. Countermeasure Susceptibility

Due to the difficulty of classifying and quantifying susceptibility to countermeasure, and because each missile may encounter different types of countermeasures, countermeasure susceptibility is measured on a qualitative scale of none, low, medium, or high.

3.3.5.9. Designated (Guidance)

Designated guidance is measured with a yes or no characterization.

3.3.5.10. Detection Range

Detection range is measured in meters.

3.3.5.11. Fire and Forget

A missile system utilizing a fire and forget guidance system is assigned a yes characterization while all other missile systems that require guidance by the gunner are assigned a characterization of no.

3.3.5.12. Fire From Enclosure

The ability of a missile system to be fired from an enclosure is measured on a qualitative scale of none (meaning the missile system cannot be fired from an

enclosure), small, medium, or large where small, medium, and large correspond to the size of the enclosure from which the missile can be fired.

3.3.5.13. Fire When Prone

The ability to fire a missile when prone is measured with a yes or no response.

3.3.5.14. Flash Signature

While the amount of flash could be described quantitatively in units such as lumens, the Study Team anticipated that this type of measurement data would not be readily available and thus, the amount of flash signature emitted is categorized qualitatively on a scale of none, low, medium, or high.

3.3.5.15. Flight Path Restrictions

The presence of flight path restrictions for a given missile is indicated by a characterization of yes while a characterization of no indicates that no flight path restrictions exist.

3.3.5.16. Gunner Guided

Missiles that utilize a gunner guidance system are given a characterization of yes while a characterization of no indicates that the missile is not gunner guided.

3.3.5.17. Horizontal Traverse

The horizontal traverse of a missile system’s field of fire is measured in degrees.

3.3.5.18. Identification Range

Identification range is measured in meters.

3.3.5.19. Maximum Depression

Maximum declination is measured in degrees below horizontal.

3.3.5.20. Maximum Effective Range

The maximum effective missile range is measured in meters.

3.3.5.21. Maximum Elevation

Maximum elevation is measured in degrees above horizontal.

3.3.5.22. Maximum Temperature

Maximum temperature is measured in degrees Fahrenheit.

3.3.5.23. Minimum Effective Range

Minimum effective range is measured in meters.

3.3.5.24. Minimum Safe Distance

Minimum safe distance is measured in meters.

3.3.5.25. Minimum Temperature

Minimum temperature is measured in degrees Fahrenheit.

3.3.5.26. Noise Signature

Although noise can be measured quantitatively in units such as decibels, as was the case with measuring the flash signature in lumens, the Study team anticipated that this type of data would not be available. Therefore, the amount of noise emitted is measured on a qualitative scale of none, low, medium, or high.

3.3.5.27. Passive IR Sight

A missile with a passive IR night sight type is given a characterization of yes while no indicates that the missile does not utilize a passive IR night sight type.

3.3.5.28. Platform Top Speed

Platform top speed is measured in miles per hour (mph).

3.3.5.29. Probability of Success

The probability of success is measured as a probability.

3.3.5.30. Recognition Range

Recognition range is measured in meters.

3.3.5.31. Restricted Rules of Engagement

If there are known instances where the missile was not allowed to be used due to rules of engagement, the characterization is yes, otherwise, it is given a characterization of no.

3.3.5.32. Self Guided

Self guidance is indicated by a yes or no characterization.

3.3.5.33. Set Up Time

Missile set up time is measured in minutes. While set up time could also be efficiently measured in seconds; however, the Study Team anticipated that on average, set up time would require several minutes.

3.3.5.34. Smoke Signature

Because the amount of smoke is difficult to measure quantitatively, a missile's smoke signature is measured on a qualitative scale of none, low, medium, or high.

3.3.5.35. Tear Down Time

As was decided for set up time, tear down time is measured in minutes as opposed to seconds as the Study Team anticipated that on average, tearing down the missile system would require several minutes.

3.3.5.36. Thermal Sight

The presence of a thermal night sight optic is indicated by a yes or no characterization.

3.3.5.37. Time of Flight to Max Range

The time of flight for a missile to reach its maximum range is measured in seconds.

3.3.5.38. Time to Reload After Firing Basic Load

The time required for the operator to reload the missile after firing the basic load is measured in minutes. The Study Team anticipated that in some cases reloading the missile would require several minutes and thus minutes were chosen over seconds as the appropriate unit of measure.

3.3.5.39. Time until First Shot

The time until first shot is measured in seconds.

3.3.5.40. Time until Second Shot

The time until second shot is measured in seconds.

3.3.5.41. Use in Dust/Sand

The ability of the missile system to operate in dust and sand is recorded on an “all or nothing” scale. If the missile can be used in dust and sand then it is given a yes characterization, otherwise, it is given a characterization of no.

3.3.5.42. Use in Fog

The ability of the missile system to operate in fog is recorded on an “all or nothing” scale. If the missile can be used in fog then it is assigned a yes characterization, otherwise, it is given a characterization of no.

3.3.5.43. Use in Other Obscurant(s)

The ability of the missile system to operate in other obscurants is recorded on an “all or nothing” scale. If the missile can be used in other obscurants then it is assigned a yes characterization, otherwise, it is given a characterization of no.

3.3.5.44. Use in Rain/Snow

Use in rain/snow is measured with a yes or no characterization with yes indicating that the missile system can operate in rain and snow and no implying the missile cannot be operated in these conditions.

3.3.5.45. Use in Smoke

The ability of the missile system to operate in smoke is recorded on an “all or nothing” scale. If the missile can be used in smoke then it is assigned a yes characterization, otherwise, it is given a characterization of no.

3.3.6. Logistical Attributes

Table 3-3 shows the score type and units of measure recommended by the Study Team for logistical attributes.

Table 3-3. Default Score Type and Units of Measure for Logistical Attributes

Logistical	Score Type	Unit of Measure
Battery Life (Optics)	Threshold	Hours
Crew Size	Categorical	One, Two, Three, Four or More
Launcher/Platform Volume	Threshold	Cubic Inches
Launcher/Platform Weight	Threshold	Pounds
Mean Time Between Failures (MTBF)	Threshold	Hours
Mean Time To Repair (MTTR)	Threshold	Hours
Missile Volume	Threshold	Cubic Inches
Missile Weight	Threshold	Pounds
Number of Shots in Basic Load	Categorical	Count
Operational Availability	Threshold	Percentage
Preventative Maintenance	Threshold	Hours per Year
Shelf Life	Threshold	Months

3.3.6.1. Battery Life

Battery life is measured in hours as the Study Team’s experience indicates that in most instances the USMC measures battery life in hours as opposed to days, months, years, etc.

3.3.6.2. Crew Size

A missile system’s crew size is measured as a count of crew members and is categorized as one, two, three, or more than three.

3.3.6.3. Launcher/Platform Volume

Launcher/platform volume is measured in cubic inches. The Study Team anticipated that in most cases (except when a missile is vehicle mounted), the volume of the launcher or platform of a CCM is most appropriately measured in cubic inches as opposed to cubic feet.

3.3.6.4. Launcher/Platform Weight

Launcher/platform weight is measured in pounds. The Study Team anticipated that in most cases (except when a missile is vehicle mounted), the weight of the launcher or platform of a CCM is most appropriately measured in pounds as opposed to tons.

3.3.6.5. Mean Time Between Failures (MTBF)

The mean time to failure of a missile system is measured in hours as the Study Team’s experience indicates that in most instances the USMC measures mean time to failure in hours as opposed to days, months, years, etc.

3.3.6.6. Mean Time to Repair (MTTR)

The mean time to repair a missile system is measured in hours as the Study Team’s experience indicates that in most instances the USMC measures mean time to repair in hours as opposed to days, months, years, etc.

3.3.6.7. Missile Volume

Missile volume is measured in cubic inches.

3.3.6.8. Missile Weight

Missile weight is measured in pounds.

3.3.6.9. Number of Shots in Basic Load

The number of shots in a basic load for a missile is the count of shots in a basic load.

3.3.6.10. Operational Availability

Operational availability is measured as the predicted percentage of missiles within the missile inventory that are available for operation at any given time.

3.3.6.11. Preventative Maintenance

Preventative maintenance is measured in hours per year.

3.3.6.12. Shelf Life

Shelf life is measured in months. The Study Team estimated that most missile systems possess a shelf life of at least a few years but chose to express the shelf life in months to create an easy comparison to deployment cycles, which are typically expressed in months.

3.3.7. Other Attributes

Table 3-4 shows the default score type and units of measure chosen by the Study Team for other attributes.

Table 3-4. Default Score Type and Units of Measure for Other Attributes

Other	Unit of Measure
Friendly Casualties per 1000 per Year	Count
Initial Training	Hours
Negligent Discharges per 1000 per Year	Count
Probability of Hang Fire	Probability
Probability of Misfire	Probability
Sustainment Training	Hours per Year

3.3.7.1. Friendly Casualties per 1000 per Year

Friendly casualties per 1000 per year simply are a count of such.

3.3.7.2. Initial Training

Initial training is measured in hours.

3.3.7.3. Negligent Discharges per 1000 per Year

Negligent discharges per 1000 per year are simply a count of such.

3.3.7.4. Probability of Hang Fire

The probability of hang fire is a probability.

3.3.7.5. Probability of Misfire

The probability of misfire is a probability.

3.3.7.6. Sustainment Training

Sustainment training is measured in hours per year, since most sustainment training must be conducted at least once a year.

4. CLOSE COMBAT MISSILE DECISION HIERARCHY

4.1. Introduction

This section of the report identifies the methodology used to establish the DH of missile attributes. A missile type was defined as a specific launcher platform, missile warhead, and sight combination.

4.2. The Decision Hierarchy Process Used

The Study Team convened numerous times in brainstorming sessions to review alternative ways to organize the CCM attributes. The Team decided that the SMART methodology for assigning weights to each attribute would work best when the number of sub-attributes emanating from any attribute in the tree was kept to a maximum of four. Team members then took the most current DH iteration and attempted to reorganize the hierarchy with that guideline in mind. Each member's alternative was reviewed and the best alternative for each branch of the DH was selected. During this process, new attributes were identified and a few were removed as being either subsumed in others or otherwise redundant. This resulted in the Close Combat Missile-Decision Hierarchy (CCM-DH) described in detail below.

4.3. The Resulting Decision Hierarchy

The DH process attempts to organize and describe the components of a problem in such a way that dissimilar attributes can contribute to the overall answer. In this study, the answer to be developed is the relative value of an individual missile. Value was determined by the Study Team to have three principal attributes: Utility, Training Requirements and Safety concerns as shown in Figure 4-1.(Blue boxes in the subsequent charts are attributes that are further decomposed into sub-attributes, green boxes are measurable attributes referred to as leaf attributes, and blue circles are connectors to other parts of the DH.) Training Requirements and Safety were considered independent of the type of combat Marines might engage in, but were considered important attributes of CCMs and thus included in the CCM-DH.

Utility was subdivided into State-on-State and Hybrid warfare. Each of those was subdivided into Logistical and Combat considerations. The Study Team decided that at least some attributes would be more or less important in state-on-state combat than in hybrid combat, including logistical attributes such as shelf life. The team further decided that the sub-levels below Logistical and Combat would be identical in organization, but likely would be assigned different weights. In addition, this organization would promote the use of sensitivity analysis to determine the breakpoints or crossover points between missile values.

Training Requirements was further subdivided into Initial Training and Sustainment Training, both of which are measurable.

Safety was broken down into the four attributes shown in Figure 4-1: Probability of Hang Fire, Probability of Misfire, and Negligent Discharges per 1000 per Year, and Friendly Casualties per 1000 per Year. Although these attributes are measurable, it is not known if the data for those measures is available. In addition, the safety aspects of future missiles that have not yet been deployed may be unknown. Should this be the

case, here or elsewhere within the CCM-DH, the weight of that attribute can be set to zero and that attribute and its sub-attributes will be excluded from the results.

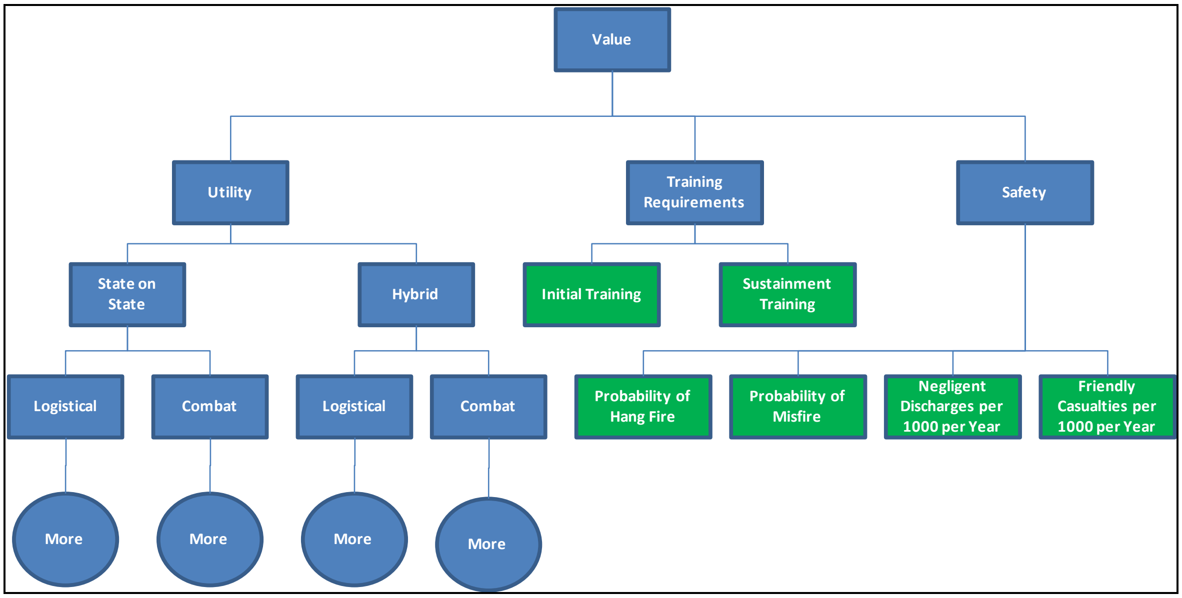

Figure 4-1. CCM-DH Top Level

The Logistical branch of the CCM-DH is shown in Figure 4-2. This branch's structure is identical regardless of its location in the State-on-State branch or Hybrid branch. Logistical considerations were subdivided into Physical Properties, Crew Size, Number of Shots in Basic Load, and Readiness. Crew Size also was placed in the Logistical branch, since the crew must be resupplied with food, water, etc. which the Study Team considered a logistics concern. The Number of Shots in a Basic Load was considered a resupply consideration, and therefore it also fell under the Logistical branch as a measurable quantity.

Figure 4-2. Logistical Branch

The Physical Properties of a CCM affect its ability to be transported operationally and tactically. Physical Properties was further subdivided into the Launcher/Platform and

Missile, since one launcher may have multiple missiles available. The two attributes, Weight and Volume for both the Launcher/Platform and Missile are restricting factors. A CCM system designed to be a single shot system has no reloads, so the weight and volume of those reloads is zero, which would give it the maximum score for those attributes.

Readiness of the CCM represented its ability to be fired when needed. Readiness was subdivided into Shelf Life, Battery Life, Maintainability, and Reliability. Shelf Life and Battery Life were measurable while Reliability was subdivided into Mean Time Between Failures and Operational Availability, both of which are measurable. Maintainability was subdivided into Preventive Maintenance requirements and Mean Time To Repair, also both measurable. That concludes the Logistical branch of the CCM-DH.

The Utility branch of the CCM-DH, shown in Figure 4-3, was divided into Maneuverability, Targeting and Acquisition, Engagement, and Force Protection/Survivability. The Utility branch attributes described the ability to move to a firing position, locate a target, fire at the target, and defend against enemy return fire. This branch's organization is identical across both types of warfare.

Maneuverability was subdivided into Platform Top Speed, Set Up time, Tear Down Time, and All Terrain capability.

Targeting and Acquisition and Engagement are expanded further below.

Force Protection/Survivability was subdivided into Armor Protection, Fire and Forget, Capture Prevention and Launch Signature. Although Fire and Forget is a type of guidance, the Study Team decided it was also a survivability feature, since the gunner does not need to remain exposed to guide the CCM to its target. Armor Protection was subdivided into Direct, for frontal protection, and Indirect, for overhead protection. Launch Signature was subdivided into Noise, Flash, and Smoke, all of which could betray the gunner's position.

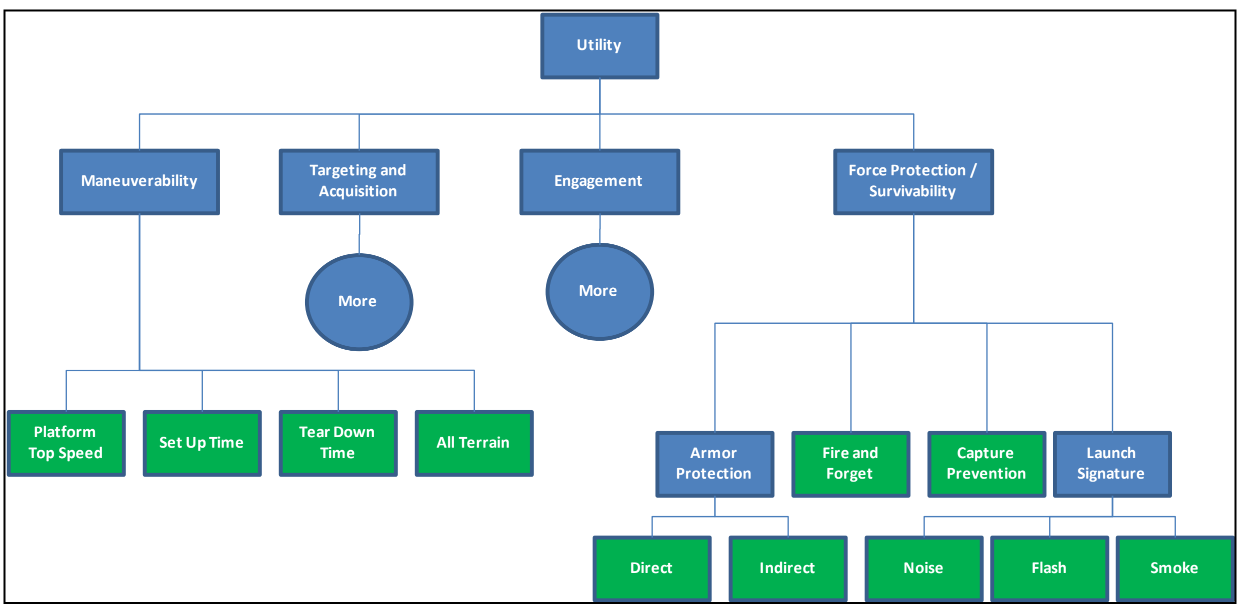

Figure 4-3. Utility Branch

The Targeting and Acquisition branch of the CCM-DH is shown in Figure 4-4 and was subdivided into Optics, Missile Restrictions, and Field of Fire. The Targeting and Acquisition branch reflected the ability to acquire a target, be in a position to fire at the target, and have the target in the field of fire of the launcher.

Optics was broken down into Range, Use in Obscurants and Night Site Type. Range was subdivided into Detection, Recognition, and Identification. Traditionally, range also includes Recognition was added to the CCM-DH as some missile systems can recognize a target outside of the missile range. Use in Obscurants was subdivided into Smoke, either deliberate or inadvertent, particulates like Dust or Sand, aerosols such as Fog, and Other to capture any other obscurants that a CCM might encounter. The Night Site Type was subdivided into the two principle technologies for night vision devices, Passive Infrared and Thermal, each of which also provided some additional capabilities and limitations.

Missile Restrictions was subdivided into Flight Path Restrictions, Firing Location, Environmental, and Restricted Rules of Engagement. Firing Location was further decomposed into Target Proximity, Fire When Prone, Fire From Enclosure, and Back Blast Area. Target Proximity was broken down into Minimum Safe Distance (from the exploding warhead) and Minimum Effective Range of the CCM. Fire From Enclosure (size of the enclosure from which the CCM can be fired). The Back Blast Area was subdivided into Angle and Distance respectively to describe the area that must remain clear when firing a CCM. Environmental was subdivided into Minimum Temperature and Maximum Temperature and Use In Rain/Snow.

Field of Fire was subdivided into Maximum Elevation, Maximum Depression, and Horizontal Traverse, all of which are measurable.

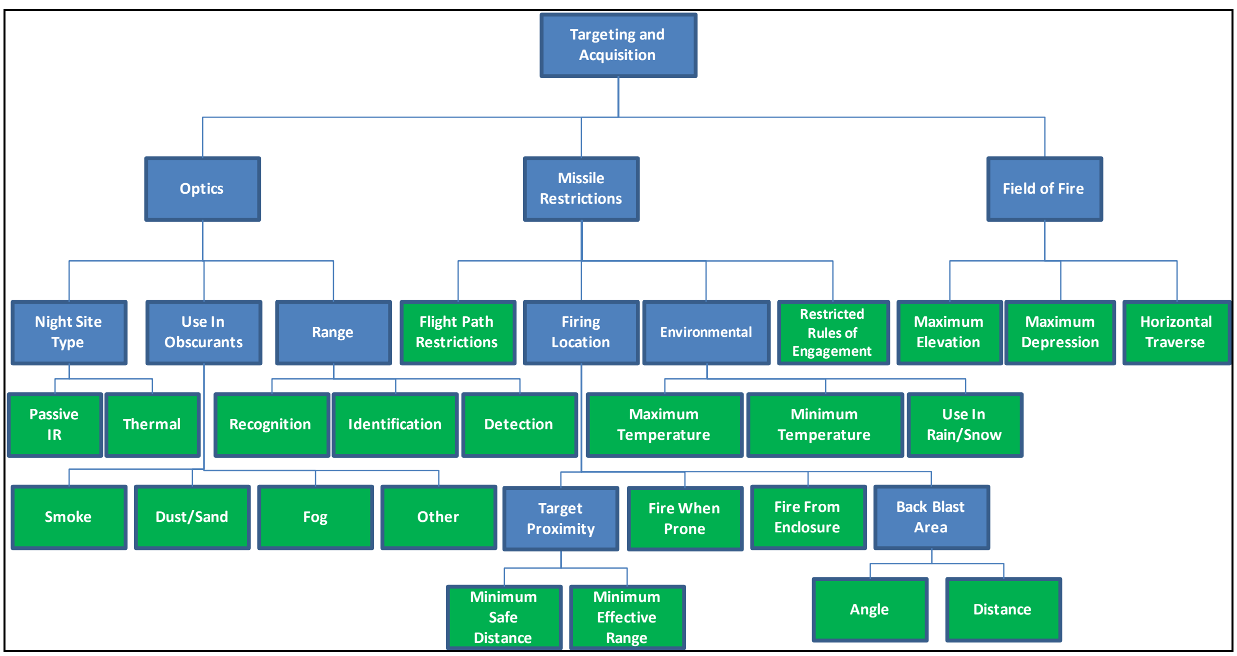

Figure 4-4. Targeting and Acquisition Branch

The Engagement branch is shown in Figure 4-5. Engagement was subdivided into Rate of Fire, Maximum Effective Range, Accuracy/Probability of Hit, and Probability of

Success. Rate of Fire was decomposed into the Time Until First Shot, Time Until Second Shot, and Time to Reload After Firing Basic Load.

Accuracy/Probability of Hit was subdivided into Time of Flight to Max Range, Guidance, and Countermeasure Susceptibility. Guidance was subdivided into Self Guided, Designated, and Gunner Guided.

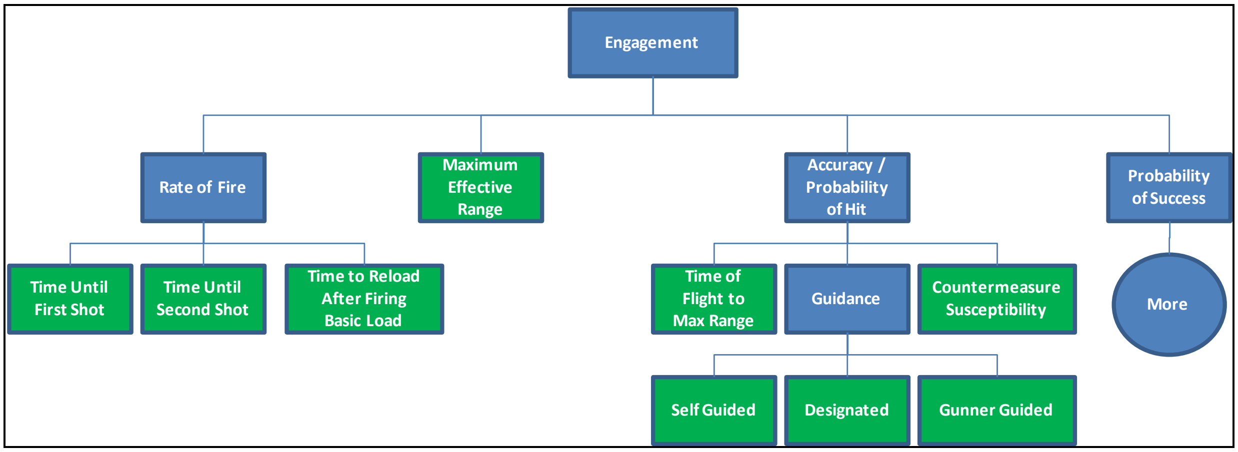

Figure 4-5. Engagement Branch

Probability of Success was further decomposed as shown in Figure 4-6. To make the CCM-DH scenario independent, it was decided that the measure of Probability of Success would be dependent on the task goal desired to accomplish. Traditionally, success is expressed as operational lethality, which is determined at the target level by measuring the probability of achieving a particular amount of damage on a target, known as K-Kill for catastrophic destruction, F-kill for eliminating a target's firepower, or M-kill for eliminating a target's ability to maneuver. The Study Team decided that this method of measuring success did not apply to structures, since a structure does not possess firepower, mobility, and for which catastrophic destruction may not be the ultimate end goal. Instead, the Study Team decided that success would be better measured through the ability to accomplish a task goal, and thus renamed it Probability of Success.

Figure 4-6. Probability of Success Branch

The task goal approach can best be described through examples. A task goal during state-on-state warfare may be to stop a main battle tank (MBT) at 3000 meters at night. A task goal in hybrid warfare may be to blow a Marine-size hole in a double brick wall. A task goal may appear in both the State-on-State and Hybrid branches of the tree, but may have different weights in each. When evaluating missile mixes, described in the next chapter, the weight of Probability of Success should be set to zero within the CCM-DH. This is because the ability of a single CCM to achieve a task goal contributes to the overall capability of the missile mix only when the quantity of the missile and the relative importance and likelihood of the task goal are also considered. The Study Team decided to include Probability of Success in the CCM-DH to allow the user to evaluate individual missiles against up to five task goals using the CCM-DH as desired. With this inclusion, the decision model possesses the capability to evaluate both individual missiles and missile mixes.

5. CLOSE COMBAT MISSILE MIX METHODOLOGY

5.1. Introduction

The objective of this methodology is to evaluate various mixes of CCMs based on their ability to accomplish task goals (capability) and their overall suitability (value). When scoring missile mixes, mixes with missiles of high value and low capability or low value and high capability should be penalized while well-rounded mixes should receive a higher score.

5.2. Evaluating a Mix of Missiles

The CCM-DH discussed in Chapter 4 was developed from a thorough review of CCM attributes with a heavy emphasis on operational utility. While the CCM-DH maybe be well suited for evaluating individual CCMs and comparing one CCM to another, it is not necessarily appropriate for evaluating missile mixes. Instead, the CCM-DH was combined with a mix methodology to calculate the capability and value of the mix to determine an overall mix score. The score calculated from the methodology is relative and dimensionless but can be compared among mixes to draw conclusions regarding the “best” mix. An overview of the mix methodology is provided in Table 5-1.

Table 5-1. Close Combat Missile Methodology Steps

Close Combat Missile Mix Methodology Steps	
Step 1	Constrain the Mix
Step 2	Define Task Goals
Step 3	Determine Probabilities of Success for Each Missile-Task Goal Combination
Step 4	Determine the Importance and likelihood of Each Task Goal
Step 5	Calculate the Mix Capability
Step 6	Calculate the Mix Value
Step 7	Determine the Emphasis of Capability vs. Value
Step 8	Calculate the Mix Score

5.2.1. Constraining the Mix

The first step in the methodology is to constrain the missile mix. This step is necessary since a mix of an infinite amount of every missile under consideration would always receive the highest score.

The user of this methodology may constrain the mix in any number of ways. These include, but are not limited to:

- Number of shots
- Total weight
- Force structure (number of Marines available to crew the weapons)
- Logistical planning factors
- Purchase price
- Life cycle cost

The constraint ideally should be based on an operational force structure. Options include:

- Rifle Platoon
- Rifle Platoon attached Assault Team from Company's Weapons Platoon
- Rifle Company
- Rifle Company with attached Platoon from Weapons Company

For example, since some of the CCMs under consideration are crew served weapons, and others are issued as individual rounds of ammunition to infantrymen, it would seem logical to separate the missiles into two categories. The first category is comprised of the heavier crew served CCMs, in which force structure is the constraining factor. Currently, HMMWV/TOW has a crew of three Marines while Javelin and SMAW each have a crew of two. The first two missile types reside in Weapons Company, the third in the Rifle Company's Weapons Platoon. The second category is comprised of lighter CCMs, e.g., LAW and AT4, which are provided to infantrymen as individual rounds and, therefore, may be more appropriately constrained by weight.

5.2.2. Task Goals List

The Study Sponsor has expressed a desire to obtain a capabilities based missile mix methodology. A capability is a capacity or potential. For the purposes of this methodology, capability is expressed as the ability to accomplish desired task goals through the employment of CCMs. It is envisioned that initially, there will be two lists of task goals, one for state-on-state warfare, and another for hybrid warfare. Figure 5-1 illustrates sample task goal statements.

	State-on-State		Hybrid Warfare
TASK GOALS	• Stop a Main Battle Tank at 2000 meters range at night • Stop a Main Battle Tank at 3000 meters in daylight • Destroy an Armored Personnel Carrier at 2500 meters • Destroy a and bag bunker at 300 meters	TASK GOALS	• Breach a triple brick wall at 50 meters • Breach a 24 inch thick adobe wall at 50 meters • Neutralize a sniper position beyond small arms range • Prevent Improvised Explosive Device Emplacement at 1000 meters

Figure 5-1. Sample Task Goal List

Since some of the task goals may appear on both lists, the two lists are then combined into a single list. For the purposes of conducting sensitivity analysis, the mix methodology retains the ability to rapidly change the relative weighting of state-on-state warfare to hybrid warfare.

Note also that the task goals include environmental considerations, such as performing the task at night, and ranges at which the task is to be performed. This is to ensure that combinations of capabilities are resident in a single missile. For example, a mix that

has one missile type that can defeat a main battle tank (MBT) at 3000 meters but only during the day, and a second missile that cannot defeat an MBT at 3000 meters but can be fired at night, would not be able to accomplish the stated task goal of defeating the MBT at 3000 meters at night.

5.2.3. Probability of Success

Each missile in the mix must be evaluated on its ability to accomplish each of the task goals, expressed as a probability, for a single shot. This estimate should consider all operational factors that would prevent a shot from being taken, such as the ability to engage, reliability, countermeasures, and the warhead's effectiveness. If some technical characteristic or environmental situation prevents that missile from being used for a specific task goal, the value for probability of success is set to zero. In addition, a missile that would not be used for a specific task goal for administrative or other rules of engagement reasons would be given a probability of success of zero. The probability is meant to capture the likelihood of success of the missile within a timeline that begins when the missile is launched and ends when the warhead detonates. Although attributes such as susceptibility to countermeasures are included in the CCM-DH, they are considered independently of all other attributes rather than as one of many contributing factors that ultimately result in the success (or failure) of a specific task goal. Because task goals are specific, the numeric values for countermeasures, probability of hit, etc. are combined into a single probability of success.

5.2.4. Operational Considerations

For each task goal, the likelihood and relative importance of the task goal to the selected unit size (if constrained by a specific unit type) in state-on-state warfare and hybrid warfare need to be developed. The likelihood of occurrence is a relative measure of expectation – how many times will a task goal need to be accomplished using CCMs rather than another task goal. Likelihood should also consider how often the task goal would be required. For example, defeating MBTs may be a frequent occurrence during state-on-state warfare, but the chance of state-on-state warfare is low. CCMs may be used relatively frequently against sniper positions in hybrid warfare, but not at all (likelihood of zero) in state-on-state warfare. A modified SMART methodology is used here as well, weighting the least frequent or least likely task goal as ten, and the rest in relative likelihood to it.

The importance of the task goal is a subjective judgment of the need for CCMs to be able to achieve the task goal. If, for example, there are many ways to achieve a task goal without employing CCMs, the importance of that task goal for CCMs would be low. If only CCMs can be used to achieve the task goal, and the goal is a worthy one, the importance would be high. It is suggested that the SMART methodology be applied here again, setting the importance of the least important task goal at ten, and then assigning values to the rest relative to the least important one.

The task goal list is evaluated twice – once from the perspective of state-on-state warfare and a second time from the perspective of hybrid warfare. For each task goal, the state-on-state likelihood and importance SMART scores are multiplied together as are the hybrid likelihood and importance SMART scores. Then the weighted sum of these values is normalized so that the task goal with the largest likelihood-importance product receives a score of 100%.

5.2.5. A Measure of Mix Capability

The next step is to determine the overall capability of a missile mix, labeled *k*. This is accomplished as follows:

I_j – The importance of task goal *j*.

L_j – The likelihood of occurrence of task goal *j*.

P_{ij} – The probability that missile *i* can accomplish task goal *j*.

Q_i – The quantity of missile type *i* in mix *k*.

C_k – The capability of missile mix *k*.

Then, if there are m missile types and n task goals,

$$C_k = \left(\prod_{j=1,n} I_j L_j \left(\sum_{i=1,m} P_{ij} Q_i\right)\right)^{(1/n)}$$

For each task goal, the ability of the mix's missiles to accomplish the task goal is calculated by multiplying the probability of task success (P_{ij}) by the number of missiles of that type in the mix (Q_i). This can be thought of as the expected number of successful task goals of type *j* that the mix can accomplish. Each task goal is weighted by its importance (I_j) and likelihood (L_j) by multiplying the sum by those two values, and then all of the task goal values are multiplied together and raised to the power *1/n*, which computes the geometric average of the capability. The geometric average is used to ensure that all the task goals are addressed by the mix. A mix for which the probability of success for all missiles in the mix against a particular task is zero will result in a zero capability to address that task goal, and give the overall mix a zero score. The geometric average will also greatly favor a high likelihood, high importance task goal over a low importance, low likelihood task goal. In addition, if all things remain equal except that the quantity of missiles is doubled, the result will be a doubling of the capability score of the mix.

Once the capability of each missile mix under consideration has been calculated, the mix capabilities are normalized on a zero to one scale (0% to 100%) by dividing the capability for each missile mix by the highest individual mix capability, resulting in a relative capability score for each mix.

5.2.6. The Value of a Mix

The CCM-DH should be used to develop a value score (H_i) for each missile in the mix, but with the weights for probability of success for each task goal set to zero within the CCM-DH. The resulting value score (H_i) is the overall value of the missile without considering its capability to achieve the set of task goals specified for the mix.

To determine the value of the mix, the value score (H_i) of each missile type should be multiplied by the quantity of each missile type (Q_i), the products summed up and divided by the total number of missiles in the mix ($\sum_{i=1,m} Q_i$) as follows:

Q_i – The quantity of missile type *i* in mix *k*.

H_i – The value score of missile type *i* in mix *k*.

V_k – The value of mix *k*.

$$V_k = \sum_{i=1,m} H_i Q_i \Big/ \sum_{i=1,m} Q_i$$

The value of the mix is not dependent upon the number of missiles in the mix. Merely having twice as many low value missiles, for example, doesn't change the value of the mix. This formulation prevents double counting of quantity in the final mix score.

Again, once the value of each missile mix under consideration has been calculated, the mix values are normalized by dividing each mix's value by the highest mix value, resulting in a relative mix value score of zero to one (0% to 100%).

5.2.7. Combining Capability and Value

The final step is to combine capability (C_k) and value (V_k) into an overall mix score. Since the user may consider the capability (C_k) of a missile mix to be more or less important than its value (V_k), a factor W must be incorporated to reflect the relative importance of value (V_k) to capability (C_k) calculated by dividing the former by the latter. If value and capability are equally important, W is 1. Additionally, W should be kept constant for all missile mixes being compared otherwise comparisons between mix values are inaccurate and inconclusive. The final calculation to obtain the mix score is:

V_k – The DH derived, normalized value of the missile mix.

W – The relative weighting of Value divided by the weighting of Capability.

C_k – The relative weighting of Capability of mix k.

S_k – The score assigned to mix k.

Then, if there are l missile mixes,

$$S_k = \sum_{k=1,l} V_k^W C_k$$

Once calculated, the mix scores are again normalized to a scale of 0 to 1, with the best mix receiving a score of one (or 100%) and the other mixes scored relative to the best mix.

(Note: Normalizing the scores at each step provides insights into the relative 'goodness' of one mix to another on a 0 to 100% scale, which is typically easier to comprehend than raw numbers, which could be quite large or quite small depending on the problem being addressed. Normalization is essential before the final score calculation because both value and capability must be on the same scale before an implication of one being more important than the other is introduced.)

5.3. Analysis of the Methodology

Since the mixes in this methodology are constrained, if two mixes are equally capable and equally valuable but there are more missiles in one mix than in the other, the mix with the greater number of missiles ($\sum_{i=1,m} Q_i$) will get the higher score. If capability (C_k) far outweighs value (V_k), then the W term will approach zero, and the value raised to the W power will approach one. A large quantity of less capable missiles may be as good as fewer, more capable missiles, but the number of task goals achieved by each constrained mix should be similar.

The selection of the value for *W*, the power function that regulates the strength of value (V_k) relative to capability (C_k), may or may not have a significant impact on the results. Figure 5-2 shows the impact of varying *W* over its range on two different sets of three sample missile mixes.

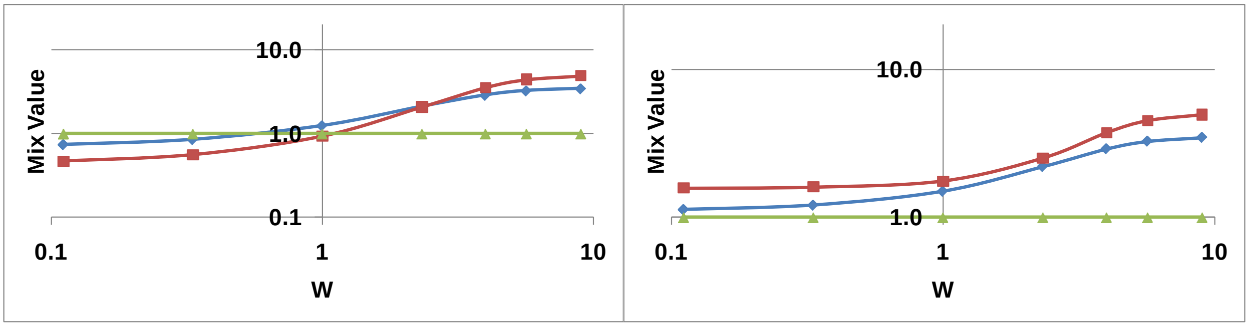

Figure 5-2. Impact of Varying W

The three mixes, shown in red, blue, and green, have had their scores divided by the green mix score for all values of W. Both scales are logarithmic. In the chart on the left, the selection of W as a very small number on the far left, where the emphasis of value is considered to be minor component of the overall score and capability is far more important, makes the green mix look the best with the highest mix score. As W is increased, increasing the emphasis on value, the scores of both the blue and red mixes increase until the blue mix score surpasses the green score. Increasing W further eventually makes the red mix have the highest score. In this case, selecting the appropriate value for W is important. However, on the right hand chart, the selection of W does not matter, since the red mix is always better than both the blue and green mixes, regardless of the value of W.

5.4. Sample Problem

The methodology is meant to be scalable. To test both the methodology and its scalability, a simple sample problem was constructed. The sample problem is to find the ‘best’ load out for a single HMMWV/TOW, which will determine the mix of missiles to buy for the fleet. The vehicle is constrained by the fact that it can only carry six missiles. There are currently three TOW missile types: the 2A direct attack, the 2B top attack, and the 2BB bunker buster. Exactly 28 possible missile mixes can be constructed from these three missile types that will fill the HMMWV/TOW vehicle. Mixes are expressed as 2A-2B-2BB.

The task goals list from Figure 5-1 was used in the sample problem. However, due to the long minimum engagement distance of the TOW missiles, the two short-range 50 meter tasks were dropped from the list as none of the missiles could achieve these task goals. Also, it was determined that the 2B missile would never be fired at a sniper.

The capability of each missile mix was determined using the CCM Decision Model, with hybrid warfare receiving a 55% allocation, and state–on-state warfare a 45% allocation. The results were normalized, resulting in the maximum relative capability score going to the 5-0-1 mix, with 6-0-0 and 4-0-2 scoring about 98% of the highest value. The 0-6-0 mix received a capability score of zero, since it was unable to address the anti-sniper task.

The value of each of the TOW missiles was computed using the CCM-DH. Training and safety issues were identical for all three TOW missiles, rendering those branches of the CCM-DH irrelevant. Similarly, all TOW missiles use the same platform, optics, etc and so, from a value perspective, there is little difference between the mixes of TOW missiles, as evidenced by the compressed range of 92% to 100%. The 2B missile was most valuable in state-on-state warfare, while the 2BB was most valuable in hybrid warfare. The 2A missile was a close second in both cases. The value for each mix was then calculated, with the most valuable mix being the 0-6-0 mix, with 1-5-0 and 0-5-1 mixes achieving 99% of the maximum value score.

Finally, the capability and value scores are combined using two different settings for W to test the sensitivity of the result to that parameter. A case where value (V_k) was half as important as capability (C_k) making W equal to 0.5, and a case where value (V_k) was twice as important as capability (C_k) making W equal to 2, was selected. The mixes, capability, value and the two scores are shown in Table 2. Note that the highest value mix received a score of zero, since its capability was rated as zero due to the inability to perform the anti-sniper mission.

Table 5-2. TOW Missile Sample Problem Results

2A	2B	2BB	C	V	Score W=2	Score W=0.5
6	0	0	**98**	**92**	**98**	**98**
5	1	0	**93**	**93**	**96**	**94**
5	0	1	**100**	**92**	**100**	**100**
4	2	0	**87**	**95**	**92**	**88**
4	1	1	**95**	**93**	**98**	**96**
4	0	2	**98**	**92**	**99**	**99**
3	3	0	**80**	**96**	**87**	**82**
3	2	1	**90**	**95**	**95**	**91**
3	1	2	**94**	**93**	**97**	**95**
3	0	3	**95**	**92**	**95**	**95**
2	4	0	**72**	**97**	**81**	**74**
2	3	1	**83**	**96**	**91**	**85**
2	2	2	**89**	**95**	**94**	**90**
2	1	3	**91**	**94**	**94**	**92**
2	0	4	**90**	**92**	**90**	**90**
1	5	0	**62**	**99**	**71**	**64**
1	4	1	**76**	**97**	**85**	**78**
1	3	2	**83**	**96**	**90**	**85**
1	2	3	**86**	**95**	**91**	**87**
1	1	4	**86**	**94**	**89**	**87**
1	0	5	**82**	**92**	**82**	**82**
0	6	0	**0**	**100**	**0**	**0**
0	5	1	**65**	**99**	**75**	**68**
0	4	2	**76**	**97**	**85**	**78**
0	3	3	**81**	**96**	**88**	**82**
0	2	4	**82**	**95**	**87**	**83**
0	1	5	**79**	**94**	**82**	**80**
0	0	6	**72**	**92**	**72**	**72**

The 5-0-1 mix has the highest score, for the two settings of W. However, 14 scores fall within 5% of the best score (highlighted). Since there is some 'fuzziness' to the methodology in that the weights, such as likelihood and importance, are based on opinions and by predicting the unpredictable, the highlighted scores in the table can be considered to be nearly identical for all practical purposes. Determining how to choose between or otherwise combine these results is outside the scope of this methodology, and will likely be problem specific.

Appendix A Acronyms

AA .... Anti-Armor
AB .... Annotated Bibliography
AHP .... Analytic Hierarchy Process
APC .... Armored Personnel Carrier
AT .... Anti-Tank
BB .... Bunker Busting
CCM .... Close Combat Missile
CCM-DH .... Close Combat Missile – Decision Hierarchy
CCMM .... Close Combat Missile Methodology
DEX .... Decision Expert
DH .... Decision Hierarchy
GCE .... Ground Combat Element
HE .... High Explosive
HEDP .... High Explosive Dual Purpose
HMMWV .... High Mobility Multipurpose Wheeled Vehicle
IED .... Improvised Explosive Device
IR .... Infrared
LAW .... Light Anti-armor Weapon
MAGTF .... Marine Air Ground Task Force
MAUT .... Multi-Attribute Utility Theory
MBT .... Main Battle Tank
MCCLL .... Marine Corps Center for Lessons Learned
MRC .... Major Regional Combat
MTTF .... Mean Time to Failure
MTTR .... Mean Time to Repair
NE .... Novel Explosive
OEF .... Operation Enduring Freedom
OIF .... Operation Iraqi Freedom
ORD .... Operational Requirements Document
PEST .... Political Economical Social Technological
SMART .... Simple Multi-Attribute Rating Technique
SMAW .... Shoulder-launched Multi-purpose Assault Weapon
SME .... Subject Matter Expert
SOS .... State- on- State
SWOT .... Strengths, Weaknesses, Opportunities, and Threats
TOW .... Tube-launched, Optically tracked, Wire guided

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Appendix C Multi-Attribute Decision Analysis

C.1 INTRODUCTION

This Appendix provides a detailed summary of the multi-attribute decision analysis approach used in this study to develop a DH for the CCMM Decision Model.

C.2 PROCEDURE FOR CREATING A VALUE MODEL USING MULTI-ATTRIBUTE DECISION ANALYSIS

Four principles underlie multi-objective decision analysis.

1. Quality decision-making requires a systematic process for incorporating information, expert opinions, and preferences.
2. Complex decisions in large organizations should involve functional experts and interested stakeholders.
3. Quantification offers significant benefits in that it clarifies thinking with respect to values, uncertainties, and consequences, improves communications, and enables logical reasoning.
4. The analysis should offer insights and support decision-maker judgments.

An important part of multi-attribute decision analysis is identifying the attributes that should drive the decision and the value of those attributes. Value-focused thinking offers several benefits such as uncovering hidden objectives, identifying decision opportunities, evaluating alternatives, guiding strategic thinking, and improving communication. The value model will facilitate stakeholder involvement in important decisions and so it must be ensured that key issues are explicitly stated.

In general, a value model is comprised of two parts – a qualitative aspect and a quantitative aspect. The qualitative aspect ensures that only the most important evaluation considerations and measures are used in the analysis. The quantitative aspect utilizes value functions and weights to evaluate the alternatives.

C.3 STEPS IN DEVELOPING A VALUE MODEL USING MULTI-ATTRIBUTE DECISION ANALYSIS

There are essentially seven steps to creating a value model using multi-attribute decision analysis. These steps are illustrated in Figure C-1.

The first step is to identify the stakeholders in the decision making process. Stakeholders are individuals or groups who have a legitimate interest or stake in both the problem and in the decision being made with respect to the problem. Thus, by identifying the stakeholders and including them in the decision-making process, their interests, and their views are taken into consideration.

The second step is to identify, with the help of the stakeholders, the intended purpose(s) of the evaluation and the available feasible alternative options. Incorporation of the stakeholders into this process ensures that their views are considered early on in the process and increases the likelihood that they will accept the eventual decision, or, at the very least, will agree that the method used to arrive at the decision is rigorous and defensible.

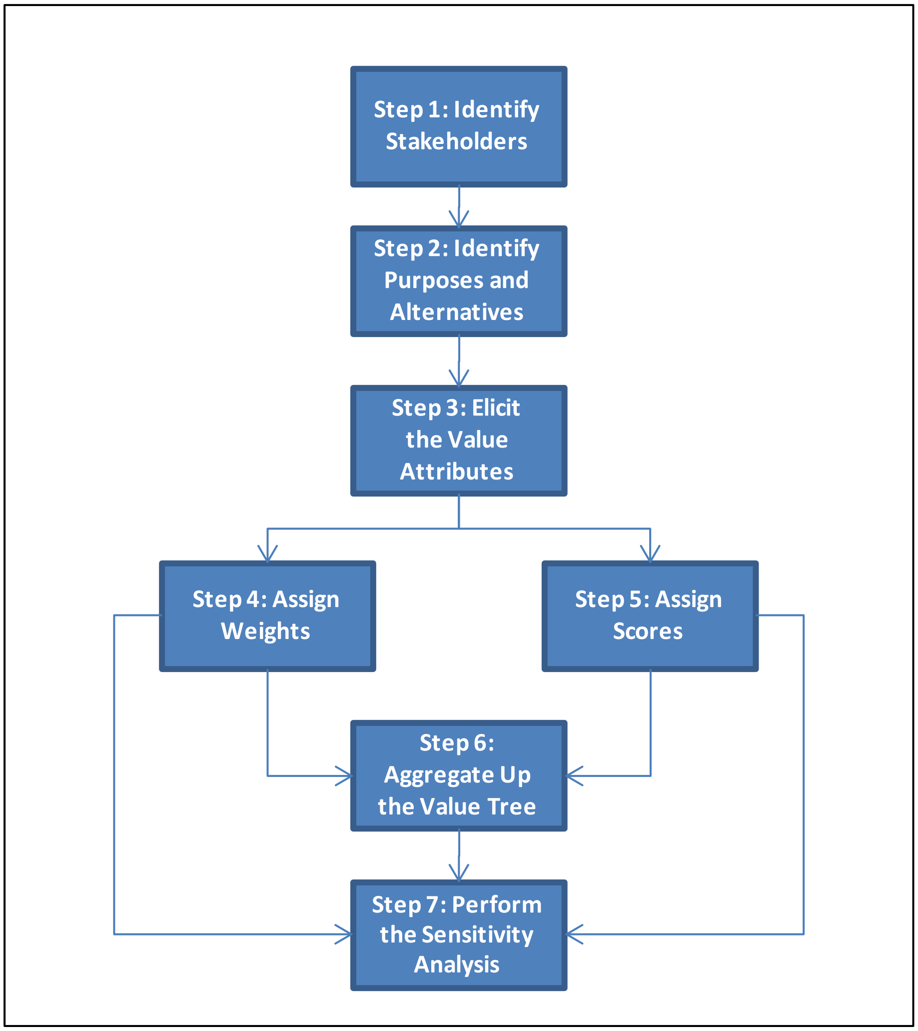


Figure C - 1. Steps in the Development of a Value Model Using Multi-Attribute Decision Analysis

Step three involves eliciting from the stakeholders the attributes relevant to the problem. These attributes are an exhaustive list of the relevant factors that must be considered in the evaluation of the alternatives. These attributes must be unique, value enhancing, and discerning between the alternatives. The attributes are organized into a decision hierarchy (or value tree) according to a natural grouping of the attributes. The organization of attributes into a decision hierarchy is discussed later.

The fourth step of the process is to determine from each stakeholder the relative importance or weight of each attribute. These weights are value judgments given to the attributes themselves by the stakeholders. They are not weights given to the alternative courses of action that are to be evaluated. These weights must be normalized to sum to one for any given level of a given branch of the tree. These weights will come under scrutiny once the evaluation has been made and could possibly be a point of potential criticism. However, if a proper sensitivity analysis is performed to show that the weights assigned are reasonable, and that only major and unreasonable changes in them will change the results of the evaluation, the model should stand up to this scrutiny.

The fifth step of the process is to determine how well each alternative satisfies each of the attributes located at the lowest level of each branch of the tree. This means that scores must be assigned to each attribute for each alternative. Different scores are assigned for each alternative under consideration as appropriate. Note, however, that more than one alternative may have the same score as another alternative for the same attribute.

Once all of the weights and scores have been determined, the overall score of each alternative is calculated by multiplying the scores and weights at each level and aggregating (summing) up the branches of the tree. In this manner, the overall scores for each alternative will have been developed both on a consistent basis and via a consistent process, and thus can then be compared directly to each other. The alternative with the highest score would offer the greatest value/utility to decision makers.

The final step of the value model process is to perform a sensitivity analysis by varying the costs, weights, and/or scores assigned in the initial evaluation. This gives the decision maker a greater feel for those factors that have driven the results. In addition, it permits further assessment of the weights and scores assigned in order to provide consistency and believability. This phase of the process, allows the decision maker to address such questions as “How high must the weight of Attribute A be raised in order for Alternative B to have the highest utility?” or “What will be the impact on the decision if the performance of Alternative B has been underestimated by 50%?” A sensitivity analysis will provide the decision makers with more confidence that the alternative chosen will hold up to any scrutiny.

C.4 ORGANIZING THE DECISION HIERARCHY

Figure C-2 is an example of a decision hierarchy (or value tree). Several important aspects of the value model methodology are illustrated here. First, the attributes are arranged in a hierarchy according to how they relate to each other. The highest level of the hierarchy is at the top and the lowest levels are at the bottom. It is at the lowest level that the scores denoted by S_{ij} or S_{ijk} are assigned for each alternative. In this illustration, blue boxes are used to represent attributes that are further broken down while green boxes represent measurable attributes. Intermediate scores, such as S_2, $S_{2,2}$, and $S_{2,2,1}$ are computed by summing the products of the scores and the weights at the lower levels of the hierarchy.

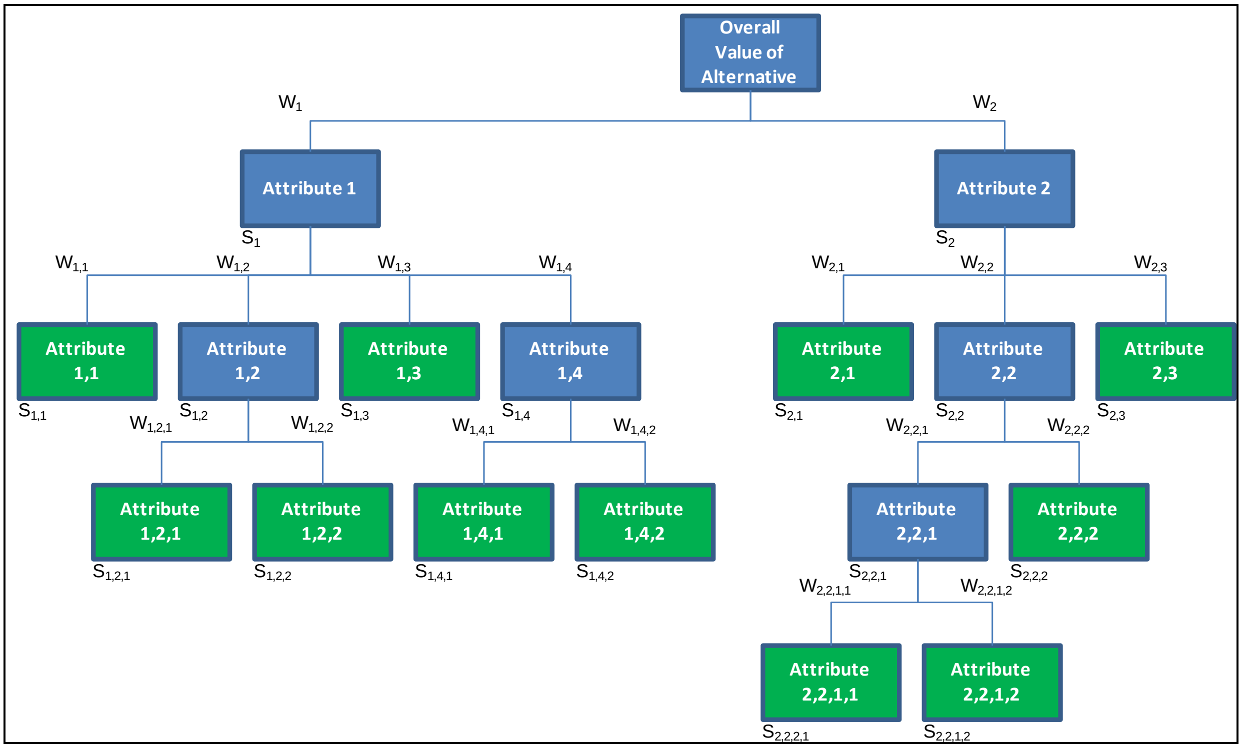


Figure C - 2. Example of a Decision Hierarchy

Note that the different levels of the hierarchy can have different numbers of sub-attributes and different numbers of sub-levels. Thus, Attribute 1 has four lower-level branches, while Attribute 2 only has three. Of the four sub-branches for Attribute 1, two do not have sub-branches, while two do. The methodology is thus flexible enough to accommodate different levels of detail assigned to the attributes and does not require the user to either generate artificial levels of detail, or to discard appropriate levels of detail because none can be generated for other attributes.

Each attribute, at every level of the tree, is assigned a weight, denoted by W_i, W_{ij}, W_{ijk}, or W_{ijkl} in the figure. Each weight is assigned to a given attribute independent of the alternative option under consideration. It should be noted that the weights do not vary as a function of the alternative being evaluated, but instead are constant across all alternatives. As stated previously, the weights at any given level of any given branch of the tree must sum to one. Thus, looking at Figure C - 2:

$$W_{1,1} + W_{1,2} + W_{1,3} + W_{1,4} = 1 \text{ and}$$

$$W_{2,1} + W_{2,2} + W_{2,3} = 1.$$

An example of the aggregation of the products of the scores and weights up the branches of the tree follows. Consider the tree pictured in Figure C-2. The first step of the aggregation process is to sum the products of the weights and scores for the attributes at the lowest levels of the tree. For this example the utility for Attribute 1,2 is determined by:

$$S_{1,2} = W_{1,2,1}*S_{1,2,1} + W_{1,2,2}*S_{1,2,2}.$$

The scores for $S_{1,4}$ and $S_{2,2,1}$ would be computed similarly. The next step in the aggregation process is to take the intermediate scores just computed and repeat the

summing of weights and scores for the next highest level within the tree. Repeating this process, the utility for Attribute 1 would be calculated as:

$$S_1 = W_{1,1}*S_{1,1} + W_{1,2}*S_{1,2} + W_{1,3}*S_{1,3} + W_{1,4}*S_{1,4}.$$

This process is continued until the top of the tree is reached. The resulting score is the overall utility for that alternative.

Appendix D Multi-Attribute Decision Methodology Details

D.1 INTRODUCTION

This Appendix provides a detailed summary of the multi-attribute decision methodologies researched during this effort, and an assessment of each methodology's utility with regard to this study.

D.2 ANALYTIC HIERARCHY PROCESS (AHP)

The AHP was developed in the 1970s by Thomas L. Saaty as a logical approach to decision making that makes use of pairwise comparisons. The AHP is a fairly in-depth method for which completion time varies based on the complexity of the decision to be made and the level at which details are considered. The AHP results in agreement by participants on the correct course of action given that the participants agree on the various weights assigned to each criterion. The AHP is used in a wide number of applications, such as scholarly research, operations research, hiring decisions, business management, and engineering projects.

There are three basic concepts in the AHP: goal, criteria, and alternatives. The goal is decomposed into criterion and sub-criterion that are organized into a decision hierarchy. The goal is the decision to be made or the question to be answered. The criteria are the factors that are taken into consideration when making the decision. Alternatives are the possible solutions that are deemed worthy of consideration. A basic graphic of the AHP is shown in Figure D-1.

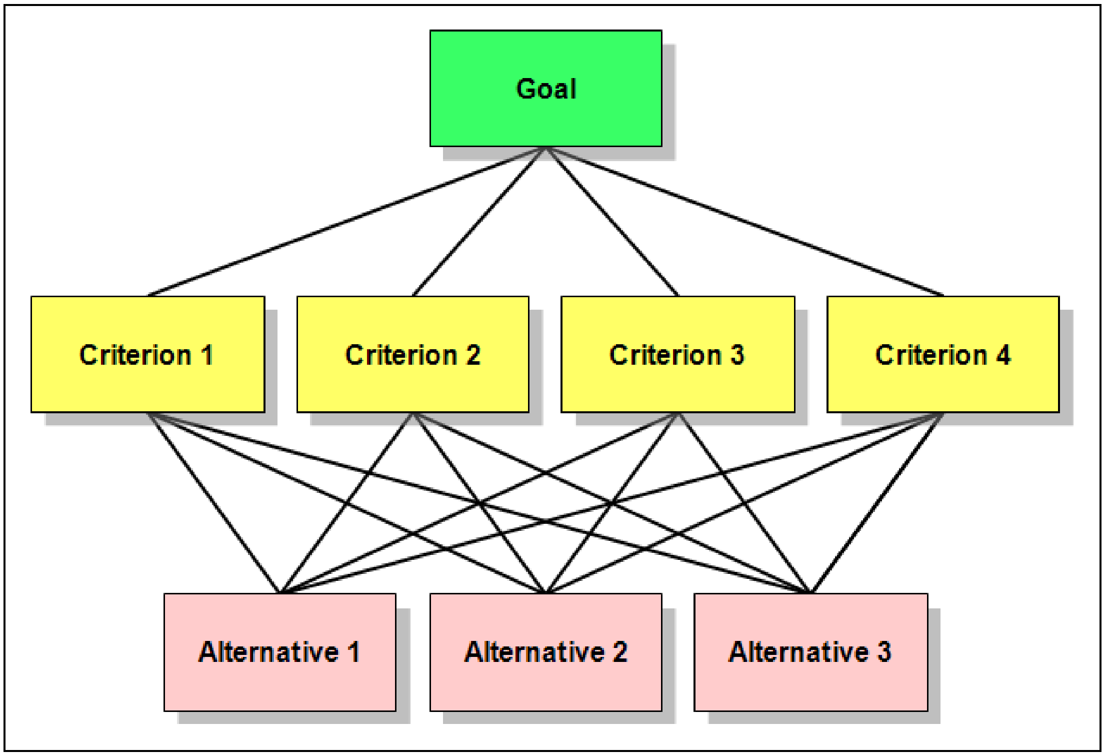


Figure D-1. Graphical Depiction of an AHP Analysis

Each criterion is assigned a local numerical weight such that the sum of all the weights for each set is one where a set is all sub-criteria linked to the same criterion or all criteria linked to the same goal. For each level of criteria, decision makers conduct pairwise comparisons of criterion (i.e., compare two at a time) within each set, choosing which criterion of the two is more important. Additionally, decision makers assign each pairwise comparison a value that scales the comparison, (i.e., how much more important is one criterion than the other, relative to the overall objective?). Mathematical calculations based on these pairwise comparisons (which often are automated with software) then determine appropriate local weights for each end sub-criterion. An example of a comparison scale is given in Figure D-2.

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

Figure D-2. Example of a Scale for Pairwise Comparisons

After local weights are determined, global weights are calculated. The global weight for each sub-criterion is the product of its local weight and its parent criterion's global weight, (at the highest level, the global weight is the local weight). Alternatives are then assigned a value equal to the weighted sum of each end sub-criterion value utilizing the global weights. The values assigned to each alternative can then be used to rank the alternatives or choose the one best suited for the decision. An example is shown in Figure D-3. (Please note that the alternatives are not shown in this graphic). Although the sub-criteria in the diagram have equal weights, this is not a requirement.

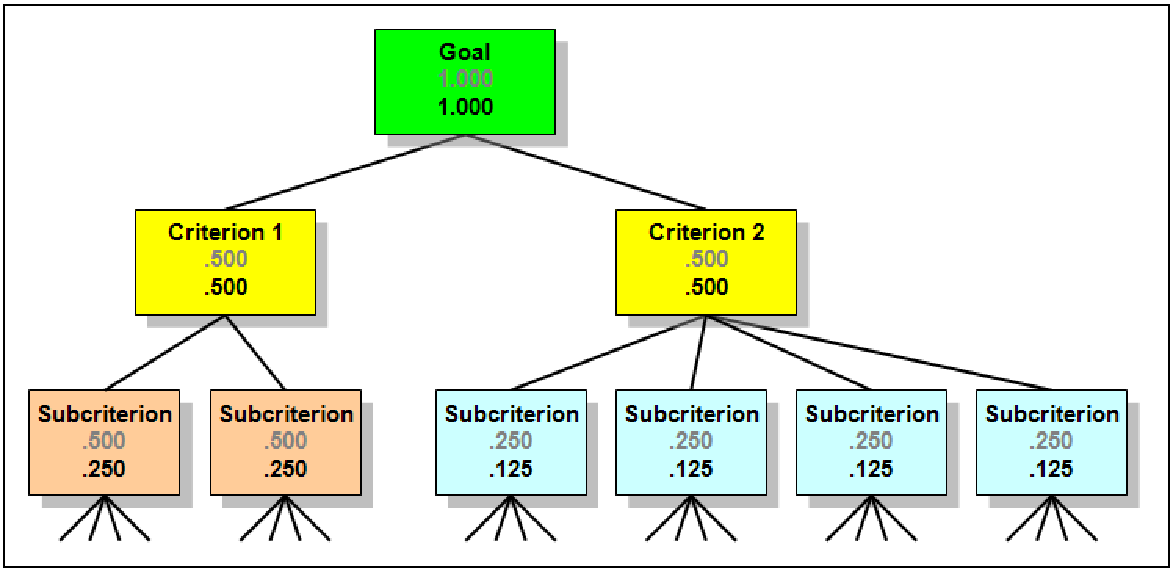


Figure D-3. Graphical Depiction of an AHP Analysis with Numerical Values for Each Criterion

The gray numerical values associated with each criterion are the local weights and will always add up to one for each set. The black numerical values associated with each criterion are the global weights with respect to the goal. The example in Figure D-3 assigns equal local weights to all criteria within each set. (Please note that in most cases, pairwise comparisons would produce results where equal weights would not be likely). Also, note that because there are six different end sub-criteria being considered in Figure D-3 then fifteen comparisons are required to determine the weights for these sub-criteria while one comparison is required to determine the weights of the first level criteria. Note that this method can be time consuming for large numbers of criteria.

AHP analysis is effective for complex problems that can be broken down into criteria and sub-criteria. Attribute scaling factors can be taken into account using an Excel spreadsheet by modifying the function that scores each mix of weapons. One potential downside of the AHP method is it becomes prohibitively large if the problem has a large number of criteria in each set. Additionally, mathematical issues may arise when calculating the weights if there are inconsistencies or complexities within the pairwise comparisons (i.e., A is more important than B, B is more important than C, but A is not more important than C).

D.3 SIMPLE MULTI-ATTRIBUTE RATING TECHNIQUE (SMART)

SMART analysis is a multi-attribute utility theory (MAUT) similar to the AHP method in that decisions are broken down into a hierarchy of criterion. Alternatives are evaluated in the same manner by assigning each alternative a value equal to the weighted sum of each end sub-criterion value. However, SMART differs from AHP in that pairwise comparisons are not used to determine individual weights for each sub-criterion. Rather, SMART utilizes swing weighting as the method for weighting all criteria. After all criteria and sub-criteria have been established, swing weighting begins by first ranking the criteria of each level in order of importance. Next, an arbitrary point value is assigned to the lowest ranking criterion. While this value is completely arbitrary, a number such as 1, 10, or 100 is recommended for simplicity. From there, the next least

important criterion is chosen and assigned a value of at least that of the lowest ranking criterion. This value is chosen in proportion to the relative importance of the lowest ranking criterion. (i.e., a value of 20 would be assigned to a criterion that is twice as important as the least important criterion that has a value of 10). This process is repeated, assigning values to each criterion in relation to the lowest ranked criterion until all criteria have been evaluated. Next, weights for each criterion are obtained by normalizing the sum of the point values to one (i.e., dividing by the sum of all values). This process is repeated for each level of the hierarchy.

An example of swing weighting is shown in Table D-1. In this example, a consumer is deciding what automobile to purchase based on four different criteria: cost, safety, style, and capacity. The second column of the table shows the values assigned from the swing weighting process. Note that style was determined to be the least important criterion receiving the lowest point value of 10 and cost was the most important criterion receiving a point value of 50. The third column of the table shows the normalization calculations performed to determine weights for each criterion.

Table D-1. Example of Swing Weighting

Attribute	Value	Weight
Cost	**50**	**50/105 = .4767**
Safety	**25**	**25/105 = .238**
Style	**10**	**10/105 = .095**
Capacity	**20**	**20/105 = .19**

A criticism of swing weighting is that relative importance may change based on inclusion of other criterion. For example, preference of criterion A to criterion B may depend on whether or not criterion C is under consideration. Additionally, when there are many different levels of criterion and sub-criterion to consider, it may become time consuming to get all decision makers to agree on an importance ranking. An advantage of SMART is that decision makers need only consider the relative importance of criteria instead of directly assigning weights and then ensuring that they add up to one. SMART would be an appropriate method for the CCMM Study because it would be relatively simple to implement in an Excel spreadsheet and because it provides a straightforward yet effective method to weight criteria.

D.4 STRENGTHS, WEAKNESSES, OPPORTUNITIES, AND THREATS (SWOT)

SWOT analysis is a decision making method developed in the 1960s by Albert Humphrey. SWOT is designed to be simple and can be performed by individuals and groups in as little as a few hours. SWOT analysis is useful for obtaining agreement on a course of action from a group of people who may have differing opinions. Business planning commonly uses SWOT analysis to decide on a course of action for a business or corporation.

Four different groups of factors are considered by the SWOT method: strengths, weaknesses, opportunities, and threats. Strengths and weaknesses are internal factors and opportunities and threats are external factors. Additionally, strengths and

weaknesses are indicative of the current situation while opportunities and threats are indicative of the future situation. It is common to create a plan to fix weaknesses and eliminate threats once a decision is made to ensure the greatest chance of success. In addition, political, economical, social, and technological (PEST) factors can be considered in the form of a PEST analysis to help identify external factors.

Figure D-4 shows a graphical depiction of a SWOT analysis conducted for business planning purposes. The outer frame classifies the groups as positive, negative, internal, or external. Each quarter of the graphic represents one of the groups in the analysis. The bullet points contained in the pentagons represent specific line items for every group.

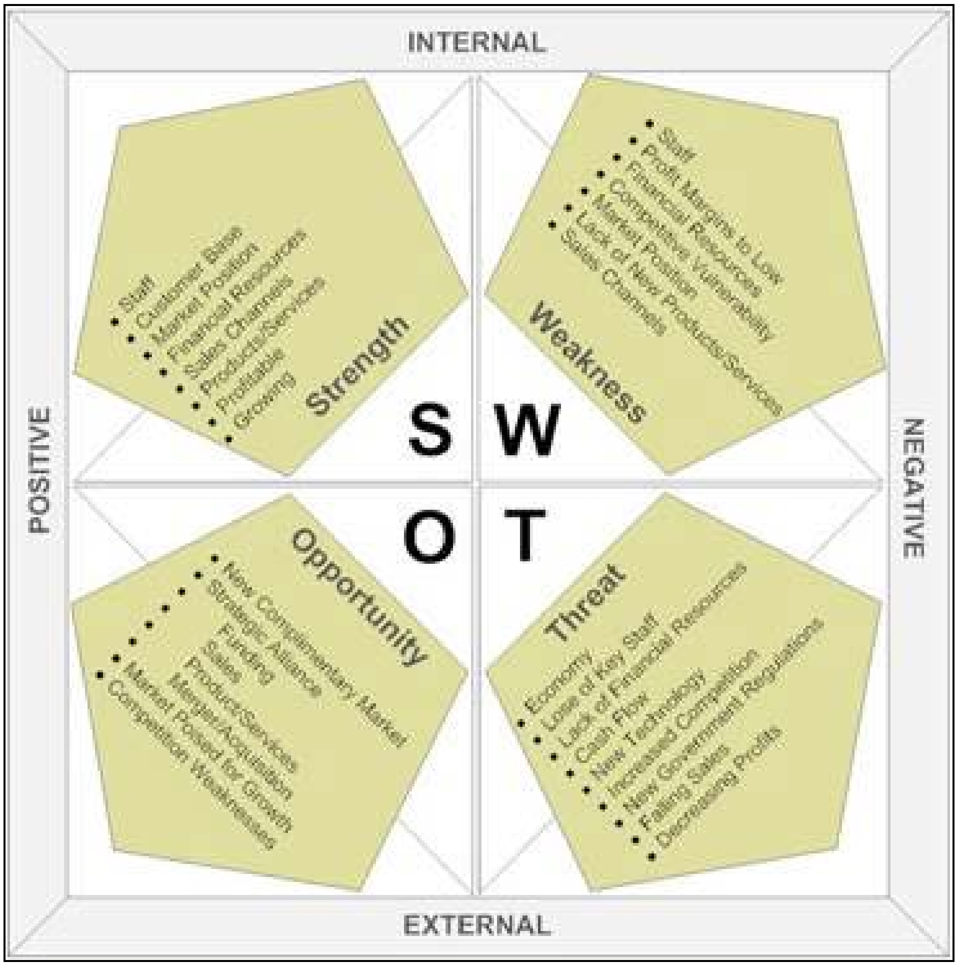


Figure D-4. Graphical Depiction of a SWOT Analysis

SWOT analysis can be combined with a weighting scheme for a clearer and more agreeable result. The participants can vote on weights for various line items within groups. If a weight for each line item can be agreed upon; it will make comparison between line items easier and make the final decision easier to explain and understand.

SWOT analysis is very effective for quick, inexpensive analysis. However, it is not well suited for the CCMM Study. While the SWOT method is good for quickly assessing an alternative, it does not have a built-in auditing mechanism. Because there is no concrete method for the participants to rank alternatives using SWOT analysis; the group may not recall how or why they came to a ranking decision, nor would

documentation describing the analysis exist. Attribute scaling factors cannot easily be taken into account using SWOT analysis. SWOT is essentially a non-mathematical method and it was unclear how to implement SWOT analysis as an automated spreadsheet for the purposes of the CCMM Study.

D.5 DECISION EXPERT (DEX)

DEX is an expert system shell for qualitative multi-attribute decision modeling and support. DEX itself is not a decision modeling method but rather a tool that aids in the evaluation of qualitative hierarchical decision modeling systems. Qualitative decision models consist of discrete attributes whose values consist of words rather than numbers. Instead of performing numerical analysis, DEX applies if-then decision rules to attributes of the model to evaluate the different options. DEX automates the revision of the decision model to account for any changes in the “weight” of certain attributes or sub-attributes as changes are made throughout the decision process. (Note that the term “weight” is used loosely here as no numeric value is actually assigned to any attribute. An example is supplied below.)

Example: Suppose a college student is using a decision model to help decide what college course to register for next semester. The factors being considered are time of day (too early/late, convenient, or perfect) and assessed difficulty of the course (easy, medium, or hard). The details of the four courses that are being considered are shown in Table D-5 along with their overall evaluation (Bad, OK, Good) based on the decision rules.

Table D-2. Factors for Consideration

Time of Day	Difficulty	Overall Course Evaluation
Too early	Medium	Bad
Perfect	Hard	OK
Convenient	Medium	Good
Too late	Easy	OK

Based on the decision rules show in Table D-5, the third course is the best option. However, if the student determines that the difficulty of the course is more important than the time of day, then a different decision rule may need to be applied. For example, the time of day could be used to eliminate options, so that only courses that were either convenient or perfect would be considered, eliminating the first and fourth courses from consideration, again leaving the third course as the preferred choice. Alternatively, the time of day could be used as a tie breaker if two courses were judged to be of similar difficulty. Table D-6 shows the revised overall course evaluations based on these new decision rules. There is only one easy course, so it is the preferred choice, and it is now the best option.

Table D-3. Revised Factors for Consideration

Time of Day	Difficulty	Overall Course Evaluation
Too early	Medium	OK
Perfect	Hard	Bad
Convenient	Medium	OK
Too late	Easy	Good

Obviously, decision models are used for more complicated decisions than that used in this example and when small changes to the decision rules

are made, they can potentially affect their parent attributes and ripple all the way up to the selection of an alternative itself. Thus, the convenience of an automated revision process becomes apparent.

The DEX methodology did not appear to be appropriate for the CCMM Study. It is a subjective, qualitative analytic tool rather than a quantitative, spreadsheet oriented decision support tool.

Appendix E Close Combat Missile Methodology Decision Model User's Guide

E.1 GENERAL INFORMATION

E.1.1 Intended Audience

This User's Manual is intended to serve as a guide for the use of the Close Combat Missile Methodology (CCMM) Decision Model. It is assumed that there is already a working knowledge of computers and Microsoft Office Excel™.

E.1.2 Purpose of the Manual

This manual is intended to assist the user with operation of the CCMM Decision Model. The manual contains descriptions of the assumptions that were made in order to create the model. The manual also includes in-depth instructions for all aspects of the model.

E.1.3 Purpose of the CCMM Decision Model

The CCMM Decision Model described in this user's manual was developed as a deliverable for the Close Combat Missile Methodology Study. The objective of this model is to evaluate mixes of close combat missiles (CCMs) as found in Marine Corps infantry units. The model takes into consideration both traditional state-on-state warfare, which includes a significant armored threat and hybrid conflicts in which the primary use of these missiles is in an anti-structure role. Missile mixes are evaluated based on the attributes of the individual missiles of which they are comprised and the mix's ability to accomplish a desired set of objectives. The value model is suitable for evaluating mixes of CCMs that include all current and projected Marine Corps systems with well known attributes.

E.1.4 System Specifications

Computer/Processor: 500 MHz

Memory: 1 GB

Display: 1024 x 768

Operating System: Windows XP or later

Required Software: Microsoft Office 2007

E.2 THE DECISION HIERARCHY (DH) METHODOLOGY

E.2.1 Introduction

As mentioned above, the CCMM Decision Model evaluates individual missiles in addition to mixes of missiles, which are evaluated based on their individual scores and their ability to achieve a desired set of task goals. A decision hierarchy (DH) of missile attributes was utilized in order to calculate individual missile scores. In general, a DH organizes and describes the components of a problem in such a way that dissimilar attributes can contribute to the overall answer. In this case, the answer to be developed is the relative value of an individual CCM and the components of the DH are the attributes of a missile. The Close Combat Missile – Decision Hierarchy (CCM-DH) allows dissimilar missile attributes to contribute to the overall score (or value) of a

missile. For the purposes of this model, a missile type is defined as a specific launcher platform, missile warhead and sight combination.

E.2.2 The Decision Hierarchy Development Process Used

The CCM-DH was developed by the Study Team via an iterative process. The DH was repeatedly modified in order to most accurately depict a natural organization of CCM attributes, as it became known by the Study Team through research. Additionally, the Study Team made an effort to maximize the utility and effectiveness of the DH by following a set of internally developed guidelines that include:

- Keeping the number of sub-attributes emanating from a single attribute within the decision hierarchy to a maximum of four (for simplicity and usability);
- Preventing double counting of attributes within the CCM-DH by allowing attributes to appear only once within the CCM-DH (In some instances an attribute clearly contributed to more than one functional area of the hierarchy; in that case the attribute was placed within the functional area that the Study Team deemed more influential to the overall utility of a CCM); and
- Using qualitative standards of measure for attributes for which the Study Team anticipated no quantitative data would be available.

E.2.3 The Resulting Decision Hierarchy

After completion of the DH process, the resulting hierarchy decomposed the value of a missile mix into three principal components: Combat Capability, Training Requirements, and Safety considerations that are each broken down further. The complete hierarchy is illustrated in both the Close Combat Model Methodology (CCMM) Draft Final Report and within the CCMM Decision Model Excel™ Workbook itself.

E.2.4 The Missile Mix Evaluation Methodology

While the CCM-DH maybe be well suited for evaluating individual CCMs and comparing one CCM to another, it is not necessarily appropriate for evaluating missile mixes. Instead, the CCM-DH was combined with a mix methodology to calculate the capability and value of the mix to determine an overall mix score. The score calculated from the methodology is relative and dimensionless but can be compared among mixes to draw conclusions regarding the “best” mix.

Each mix is constrained by the user to meet some condition external to this model. This constraining condition can be weight, force structure, cost, etc. or a combination of conditions, and determines the number of missiles in each candidate mix.

Next, the capability of the missile mix is determined by the mix’s ability to accomplish a set of task goals, expressed as a probability of success. Each task goal is given an importance, using the SMART methodology, and an anticipated relative likelihood of occurrence, which also is determined using the SMART methodology. The value of the mix is then computed utilizing the individual missile type scores from the CCM-DH and weighting by the quantity of each missile type in the mix.

Finally, the relative emphasis of value vs. capability is determined so that value and capability can then be combined to arrive at an overall score for the missile mix.

E.3 USING THE CCMM DECISION MODEL

E.3.1 About the Workbook

The CCMM Decision Model consists of a single Excel™ Workbook. The workbook consists of 80 worksheets. Six of these worksheets require user input to run the model while the remaining 72 serve as display pages for in-depth user review of the CCM-DH details used in the value model.

The worksheets of the CCM Decision Model Workbook are protected to prevent inadvertent deletion or overwriting of important cell formulas or contents. If the user attempts to click on or edit a locked cell a message box (shown in Figure E-1) will appear. It is recommended that the worksheets remain protected except during workbook maintenance.

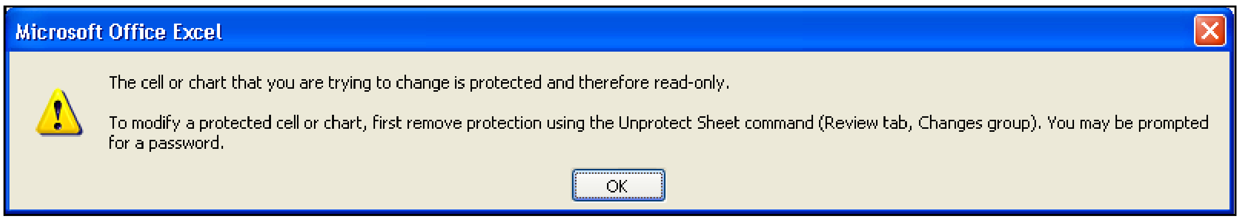


Figure E-1 Cell Protection Warning

Throughout the CCM Decision Model Workbook, cells highlighted in yellow are unlocked cells that are available for user editing. Users may enter or paste data into these cells. When pasting data, it is recommended that the user select the “Paste Special” option to “Paste Value” only. Otherwise, the user runs the risk of entering invalid formulas that may damage or overwrite model commands. To paste values into a cell, click “Paste” on Excel ribbon and then select “Paste Values” from the drop-down menu. This menu is shown in Figure E-2.

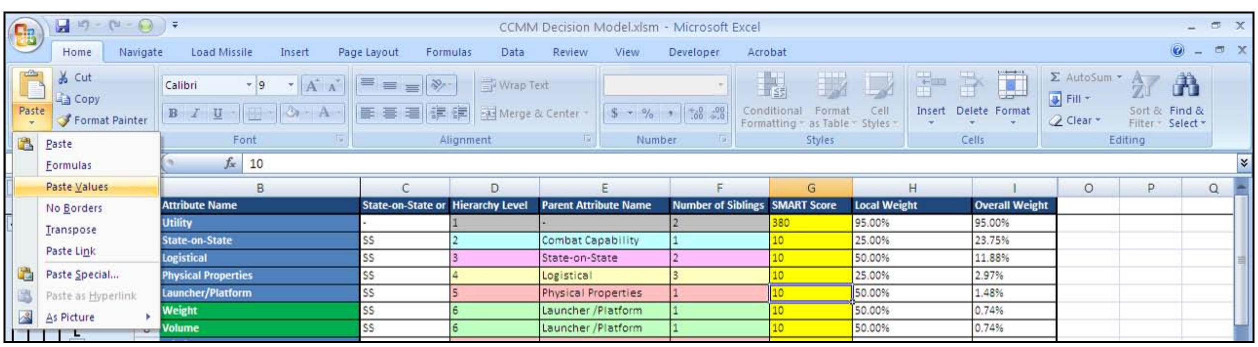


Figure E-2. “Paste Value” from the Excel Ribbon

E.3.2 Overview Worksheet

The Overview worksheet displays the CCM-DH and shows how all attributes and sub-attributes are related. Attributes represented by blue boxes are further broken down into sub-attributes while green boxes represent leaf attributes of the CCM-DH. Leaf attributes have no children within the DH and thus are the only attributes for which scores must be directly entered by the user. Non-leaf attribute scores are automatically calculated by multiplying the scores and weights at each level and aggregating (summing) up the branches of the CCM-DH. As will be discussed later in this manual,

links to the Overview worksheet are provided on all worksheets for which user input may require reference to an attribute or group of attributes within a specific location of the CCM-DH. The Overview worksheet is provided for user reference only and does not perform any calculation functions. The "Overview Worksheet" is displayed in Figure E-3.

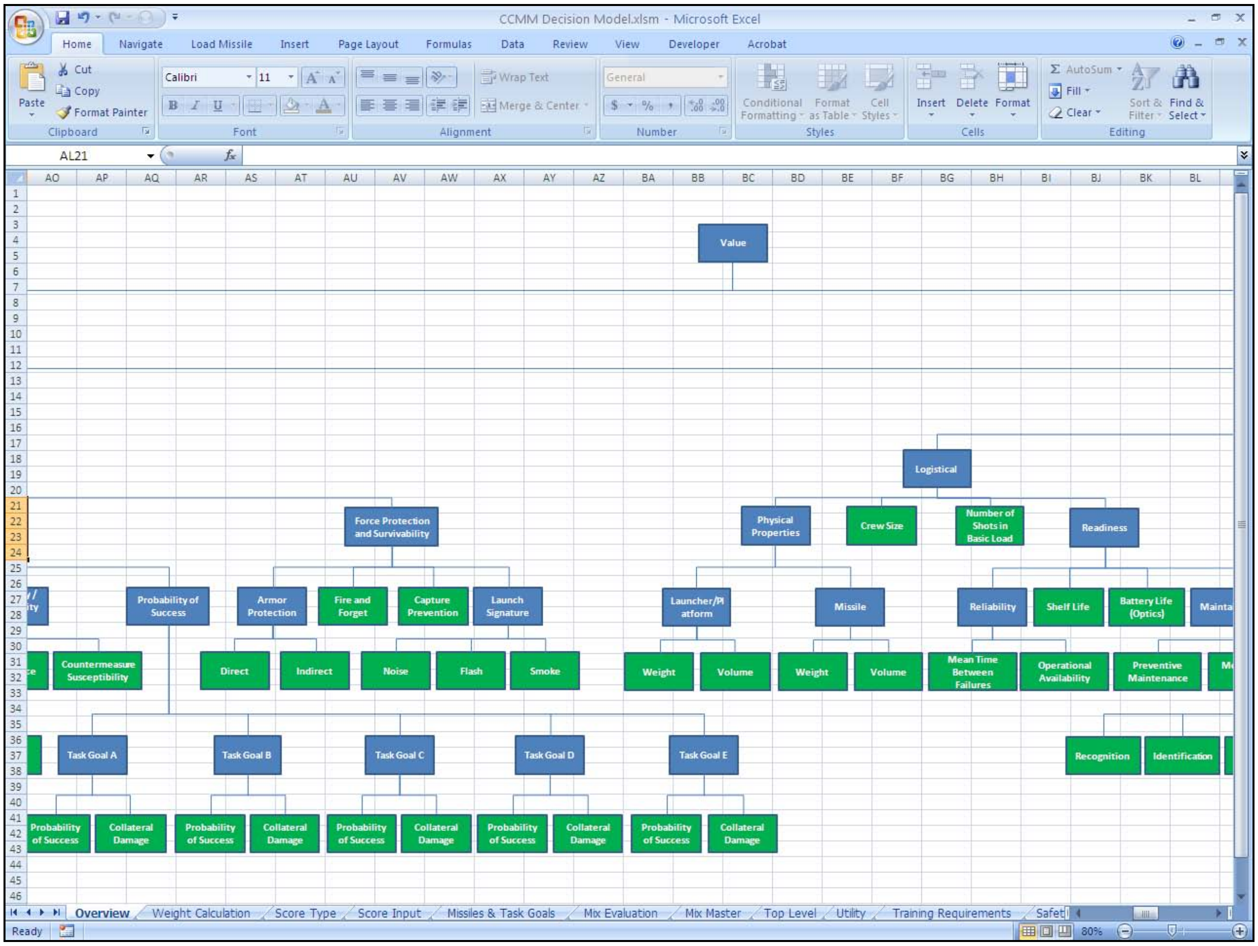
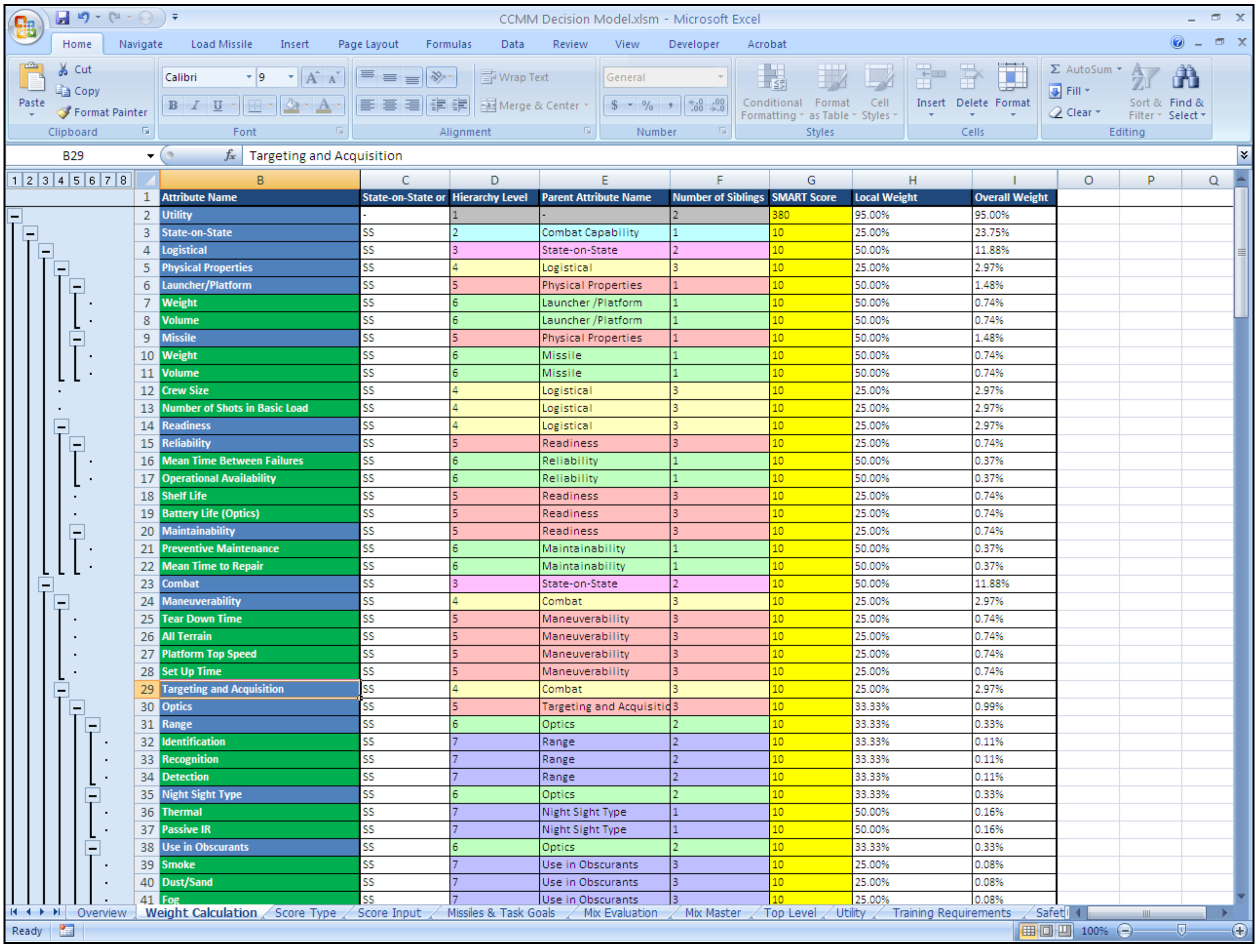


Figure E-3. The "Overview" Worksheet

E.3.3 Weight Calculation Worksheet

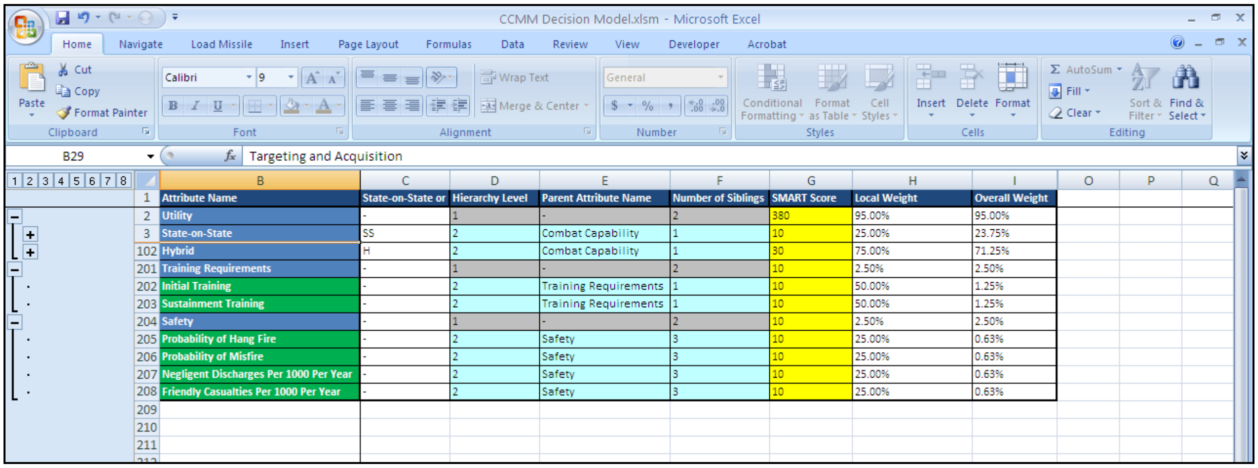
The "Weight Calculation" worksheet allows users to assign weights to each attribute of the CCM-DH. The "Weight Calculation" worksheet is shown in Figure E-4.



	Attribute Name	State-on-State or	Hierarchy Level	Parent Attribute Name	Number of Siblings	SMART Score	Local Weight	Overall Weight
2	Utility	-	1	-	2	380	95.00%	95.00%
3	State-on-State	SS	2	Combat Capability	1	10	25.00%	23.75%
4	Logistical	SS	3	State-on-State	2	10	50.00%	11.88%
5	Physical Properties	SS	4	Logistical	3	10	25.00%	2.97%
6	Launcher/Platform	SS	5	Physical Properties	1	10	50.00%	1.48%
7	Weight	SS	6	Launcher /Platform	1	10	50.00%	0.74%
8	Volume	SS	6	Launcher /Platform	1	10	50.00%	0.74%
9	Missile	SS	5	Physical Properties	1	10	50.00%	1.48%
10	Weight	SS	6	Missile	1	10	50.00%	0.74%
11	Volume	SS	6	Missile	1	10	50.00%	0.74%
12	Crew Size	SS	4	Logistical	3	10	25.00%	2.97%
13	Number of Shots in Basic Load	SS	4	Logistical	3	10	25.00%	2.97%
14	Readiness	SS	4	Logistical	3	10	25.00%	2.97%
15	Reliability	SS	5	Readiness	3	10	25.00%	0.74%
16	Mean Time Between Failures	SS	6	Reliability	1	10	50.00%	0.37%
17	Operational Availability	SS	6	Reliability	1	10	50.00%	0.37%
18	Shelf Life	SS	5	Readiness	3	10	25.00%	0.74%
19	Battery Life (Optics)	SS	5	Readiness	3	10	25.00%	0.74%
20	Maintainability	SS	5	Readiness	3	10	25.00%	0.74%
21	Preventive Maintenance	SS	6	Maintainability	1	10	50.00%	0.37%
22	Mean Time to Repair	SS	6	Maintainability	1	10	50.00%	0.37%
23	Combat	SS	3	State-on-State	2	10	50.00%	11.88%
24	Maneuverability	SS	4	Combat	3	10	25.00%	2.97%
25	Tear Down Time	SS	5	Maneuverability	3	10	25.00%	0.74%
26	All Terrain	SS	5	Maneuverability	3	10	25.00%	0.74%
27	Platform Top Speed	SS	5	Maneuverability	3	10	25.00%	0.74%
28	Set Up Time	SS	5	Maneuverability	3	10	25.00%	0.74%
29	Targeting and Acquisition	SS	4	Combat	3	10	25.00%	2.97%
30	Optics	SS	5	Targeting and Acquisitio	3	10	33.33%	0.99%
31	Range	SS	6	Optics	2	10	33.33%	0.33%
32	Identification	SS	7	Range	2	10	33.33%	0.11%
33	Recognition	SS	7	Range	2	10	33.33%	0.11%
34	Detection	SS	7	Range	2	10	33.33%	0.11%
35	Night Sight Type	SS	6	Optics	2	10	33.33%	0.33%
36	Thermal	SS	7	Night Sight Type	1	10	50.00%	0.16%
37	Passive IR	SS	7	Night Sight Type	1	10	50.00%	0.16%
38	Use in Obscurants	SS	6	Optics	2	10	33.33%	0.33%
39	Smoke	SS	7	Use in Obscurants	3	10	25.00%	0.08%
40	Dust/Sand	SS	7	Use in Obscurants	3	10	25.00%	0.08%
41	Fog	SS	7	Use in Obscurants	3	10	25.00%	0.08%

Figure E-4. The "Weight Calculation" Worksheet

The "Attributes" column lists the attributes of the CCM-DH. Leaf attribute names have a green fill color while non-leaf attribute names have a blue fill color. The attributes are organized in accordance with the structure of the CCM-DH with parent attributes listed above children attributes. The list of attributes can be expanded and collapsed by utilizing the two different types of outline buttons located on the far left of the worksheet. Across the top of the blue outline section of the worksheet is a row of buttons labeled one through eight. These buttons correspond to the eight levels of the CCM-DH. Clicking on a numbered button will display the attributes up to that level of the CCM-DH and hide all other attributes. For example, Figure E-5 shows the attributes that are displayed when the outline button labeled "2" is clicked. To view all attributes, click on the "8" outline button. Additionally, the "+" and "-" outline buttons expand and collapse individual parent attributes. Clicking on a "+" outline button for an attribute will expand the list of attributes to include the children of the attribute. Clicking on a "-" outline button for an attribute will collapse the list of attributes to hide the children of the attribute.



	Attribute Name	State-on-State or	Hierarchy Level	Parent Attribute Name	Number of Siblings	SMART Score	Local Weight	Overall Weight
2	Utility	-	1	-	2	380	95.00%	95.00%
3	State-on-State	SS	2	Combat Capability	1	10	25.00%	23.75%
102	Hybrid	H	2	Combat Capability	1	30	75.00%	71.25%
201	Training Requirements	-	1	-	2	10	2.50%	2.50%
202	Initial Training	-	2	Training Requirements	1	10	50.00%	1.25%
203	Sustainment Training	-	2	Training Requirements	1	10	50.00%	1.25%
204	Safety	-	1	-	2	10	2.50%	2.50%
205	Probability of Hang Fire	-	2	Safety	3	10	25.00%	0.63%
206	Probability of Misfire	-	2	Safety	3	10	25.00%	0.63%
207	Negligent Discharges Per 1000 Per Year	-	2	Safety	3	10	25.00%	0.63%
208	Friendly Casualties Per 1000 Per Year	-	2	Safety	3	10	25.00%	0.63%

Figure E-5. Attributes Up to Level 2 of the CCM-DH

Because the State-on-State and Hybrid branches are identical, the “State-on-State or Hybrid” column indicates to which branch each attribute belongs. An “H” indicates that the attribute falls under the Hybrid branch while an “SS” indicates that the attribute falls under the “State-on-State” branch. The value for this indicator is left blank for attributes to which it is not applicable (i.e., Utility; because it appears higher in the CCM-DH than both State-on-State and Hybrid). Both the “Attributes” and “State-on-State or Hybrid” columns are locked as these values are not input values and should not be edited or deleted by the user.

The “Hierarchy Level” column displays the level of the CCM-DH in which the attribute appears. Levels are numbered with the highest level of the CCM-DH assigned a value of one and each level below increasing by one in value. The “Parent Attribute Name” column displays the name of the attribute’s parent. A parent attribute is the distinct attribute of the CCM-DH from which an attribute branches off. The “Number of Siblings” column displays the number of attributes on the same level of the DH possessing the same parent. Attributes should be weighted utilizing the SMART technique in which each attribute within the CCM-DH is weighted relative to its siblings, assigning the least important attribute a value of ten and the remaining attributes values of at least ten based on their importance as compared to the least important attribute.

The purpose of the “Parent Attribute Name” and “Number of Siblings” columns is to provide the user with the context in which each attribute is to be weighted. To navigate to the location of the attribute within the “Overview” worksheet, double click on an attribute name in the “Attributes” column. To get back to the “Weight Calculation” worksheet, click on the attribute while still in the “Overview” worksheet. Figure E-6 shows the location within the “Overview” worksheet to which the user is navigated after clicking on the “Number of Shots in a Basic Load” attribute for state-on-state warfare.

The “Hierarchy Level,” “Parent Attribute Name,” and “Number of Siblings” cells for each attribute are given a fill color based on the level of the CCM-DH on which the attribute appears as indicated in the “Hierarchy Level” column. For example, as can be seen previously in Figure E-6, all attributes of Level 2 of the CCM-DH have a light blue fill color for those columns.

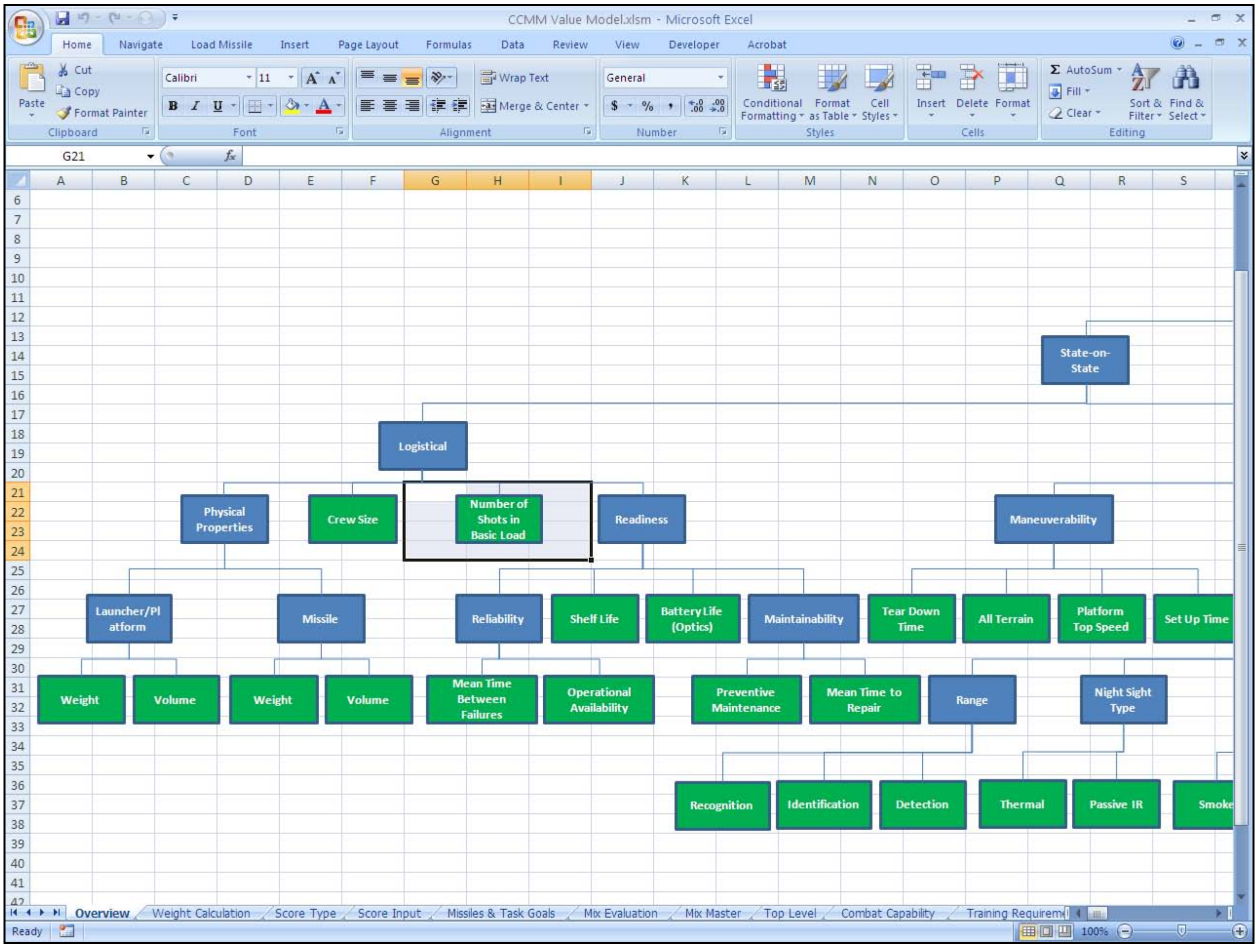


Figure E-6. Navigation to “Number of Shots in Basic Load” in the “Overview” Worksheet

Every cell except for those in the “SMART Score” column is locked as user edits are only permitted within this column. The cells of the “SMART Score” column are highlighted in yellow indicating that user input is required to calculate overall weight values for each attribute. To enter a SMART score for an attribute, enter a value of zero or at least ten in the “SMART Score” column for the appropriate attribute. Because the user may wish not to consider certain attributes, entering a SMART score of zero assigns the attribute a weight of zero. However, if an attribute is to be considered in the CCM-DH, then a value of at least ten must be entered to keep consistent with the SMART technique. Note that for evaluating mixes of missiles, “Probability of Success” under both state-on-state and hybrid warfare should be set to zero because probability of success is taken into consideration later within the missile mix methodology. If a value other than zero and less than ten is entered as a SMART score for any attribute a message box (shown in Figure E-7) will appear prompting the user to enter a value of zero or at least ten.

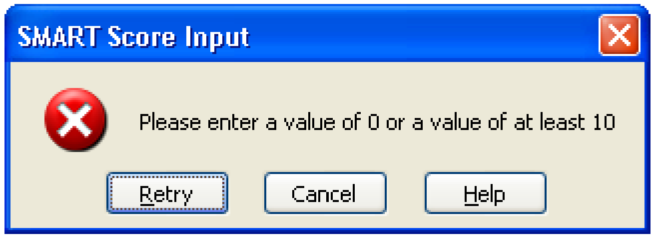


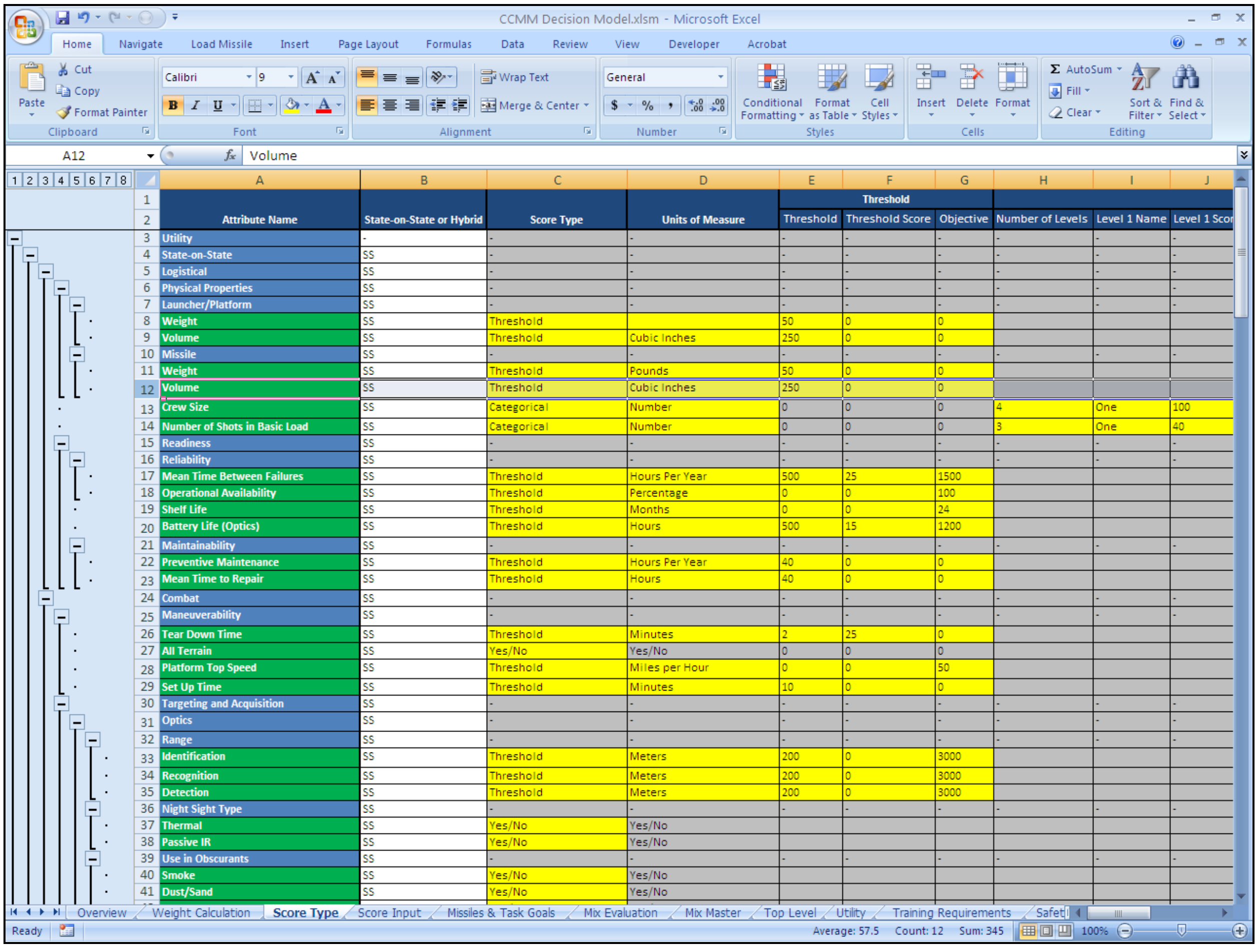
Figure E-7. The SMART Score Invalid Value Message Box

The “Local Weight” column displays the weight of an attribute relative to its sibling attributes by apportioning the SMART scores by dividing each SMART score by the sum of all smart scores for that attribute sub-family. The “Overall Weight” column displays the overall weight of an attribute as it contributes to the final CCM-DH score for a missile. The overall weight for each attribute is calculated by starting at the top of the CCM-DH and multiplying each child attribute’s local weight by its parent attribute’s overall weight. (This is trivial for the first two levels of the CCM-DH). This method is repeated aggregating (multiplying) the overall weights down the CCM-DH by the parent’s local weight until an overall weight has been calculated for each attribute. Both the “Local Weight” and “Overall Weight” columns are locked as these values are not input values and should not be edited or deleted by the user.

E.3.4 Score Type Worksheet

The Score Type worksheet shown in Figure E-8 allows the user to select the type of score to be assigned to each leaf attribute within the CCM-DH. The “Attributes” column lists the attributes of the CCM-DH. Leaf attributes have a green fill color while non-leaf attributes have a blue fill color. The attributes are organized in accordance with the structure of the CCM-DH with parent attributes listed above children attributes. The list of attributes can be expanded and collapsed by utilizing the two different types of outline buttons located on the far left of the worksheet. Across the top of the blue outline, section of the worksheet is a row of buttons labeled one through eight. These buttons correspond to the eight levels of the CCM-DH. Clicking on a numbered button will display the attributes up to that level of the CCM-DH and hide all other attributes. Additionally, the “+” and “-” outline buttons expand and collapse individual parent attributes. Clicking on a “+” outline button for an attribute will expand the list of attributes to include the children of the attribute. Clicking on a “-” outline button for an attribute will collapse the list of attributes to hide the children of the attribute.

Because the State-on-State and Hybrid branches are identical, the “State-on-State or Hybrid” column indicates to which branch each attribute belongs. An “H” indicates that the attribute falls under the Hybrid branch while an “SS” indicates that the attribute falls under the “State-on-state” branch. The value for this indicator is left blank for attributes to which it is not applicable (i.e., Combat Capability; because it appears higher in the CCM-DH than both State-on-State and Hybrid). Both the “Attributes” and “State-on-State or Hybrid” columns are locked as these values are not input values and should not be edited or deleted by the user.



	A	B	C	D	E	F	G	H	I	J
1					Threshold					
2	Attribute Name	State-on-State or Hybrid	Score Type	Units of Measure	Threshold	Threshold Score	Objective	Number of Levels	Level 1 Name	Level 1 Scor
3	Utility	-	-	-	-	-	-	-	-	-
4	State-on-State	SS	-	-	-	-	-	-	-	-
5	Logistical	SS	-	-	-	-	-	-	-	-
6	Physical Properties	SS	-	-	-	-	-	-	-	-
7	Launcher/Platform	SS	-	-	-	-	-	-	-	-
8	Weight	SS	Threshold		50	0	0			
9	Volume	SS	Threshold	Cubic Inches	250	0	0			
10	Missile	SS	-	-	-	-	-	-	-	-
11	Weight	SS	Threshold	Pounds	50	0	0			
12	Volume	SS	Threshold	Cubic Inches	250	0	0			
13	Crew Size	SS	Categorical	Number	0	0	0	4	One	100
14	Number of Shots in Basic Load	SS	Categorical	Number	0	0	0	3	One	40
15	Readiness	SS	-	-	-	-	-	-	-	-
16	Reliability	SS	-	-	-	-	-	-	-	-
17	Mean Time Between Failures	SS	Threshold	Hours Per Year	500	25	1500			
18	Operational Availability	SS	Threshold	Percentage	0	0	100			
19	Shelf Life	SS	Threshold	Months	0	0	24			
20	Battery Life (Optics)	SS	Threshold	Hours	500	15	1200			
21	Maintainability	SS	-	-	-	-	-	-	-	-
22	Preventive Maintenance	SS	Threshold	Hours Per Year	40	0	0			
23	Mean Time to Repair	SS	Threshold	Hours	40	0	0			
24	Combat	SS	-	-	-	-	-	-	-	-
25	Maneuverability	SS	-	-	-	-	-	-	-	-
26	Tear Down Time	SS	Threshold	Minutes	2	25	0			
27	All Terrain	SS	Yes/No	Yes/No	0	0	0			
28	Platform Top Speed	SS	Threshold	Miles per Hour	0	0	50			
29	Set Up Time	SS	Threshold	Minutes	10	0	0			
30	Targeting and Acquisition	SS	-	-	-	-	-	-	-	-
31	Optics	SS	-	-	-	-	-	-	-	-
32	Range	SS	-	-	-	-	-	-	-	-
33	Identification	SS	Threshold	Meters	200	0	3000			
34	Recognition	SS	Threshold	Meters	200	0	3000			
35	Detection	SS	Threshold	Meters	200	0	3000			
36	Night Sight Type	SS	-	-	-	-	-	-	-	-
37	Thermal	SS	Yes/No	Yes/No						
38	Passive IR	SS	Yes/No	Yes/No						
39	Use in Obscurants	SS	-	-	-	-	-	-	-	-
40	Smoke	SS	Yes/No	Yes/No						
41	Dust/Sand	SS	Yes/No	Yes/No						

Figure E-8. The "Score Type" Worksheet

The "Score Type" column allows the user to select a score type for each leaf attribute from a drop-down menu. The six score types are Threshold, Yes/No, No/Yes, None/Low/Medium/High, High/Medium/Low/None, and Enumeration. Exactly one score type for each leaf attribute must be selected from the drop-down menu in the "Score Type" column. Recommended units of measure are the default settings initially provided. Note that leaf attribute scores are the only scores directly entered by the user so "Score Type" values for non-leaf attributes are grayed out and locked while the "Score Type" cells in rows corresponding to leaf attributes are highlighted in yellow indicating user edits to these cells are permissible. The "Units of Measure" column allows the user to enter units of measure or automatically specifies the units of measure based on the score type selected for the attribute.

E.3.4.1 Threshold Score Type

The "Threshold" score type is a linear scoring method that requires the user to specify three separate values for an attribute before an attribute accurately can be scored: a threshold, a threshold score, and an objective. The threshold is the minimum value considered acceptable for an attribute and the threshold score (which can be non-zero) is the score earned by a CCM that exactly achieves the threshold for that attribute. The objective is the minimum value for which an attribute can achieve the maximum score. Attributes with values below the threshold achieve a score of zero. Attributes with values in between the threshold and objective are scored linearly between the threshold

score and 100% (which is always the maximum score for an attribute) while attributes with values equal to the objective or higher receive a score of 100.

In some cases, the desired value for a characteristic is a low one, rather than a high one. For example, for the attribute “Probability of Hangfire” a low probability is desirable. The user might assign a threshold of 0.05, a threshold score of zero, and an objective of 0.01. In other words, any missile with a probability of hangfire exceeding 0.05 will receive a score of zero for the “Probability of Hangfire” attribute while any missile with a probability of hangfire less than 0.01 will receive a score of 100 for the “Probability of Hangfire” attribute. A missile with a probability of hangfire of 0.025 will receive a score of 62.5, which is linearly interpolated between 0 and 100.

To specify a Threshold score type for an attribute, select “Threshold” from the drop-down menu in the “Score Type” column for the appropriate attribute as shown in Figure E-9. Once “Threshold” is selected as the score type, then the cells of the attribute row under the “Units of Measure,” “Threshold,” “Threshold Score,” and “Objective” sub-columns are highlighted in yellow indicating that user inputs to these cells is required. Cells in the sub-columns of the “Enumeration” column are grayed out and locked indicating that these values are not required to calculate the score for the attribute. These locked cells will not be available for editing unless the Enumeration score type is selected as the score type of choice for the attribute.

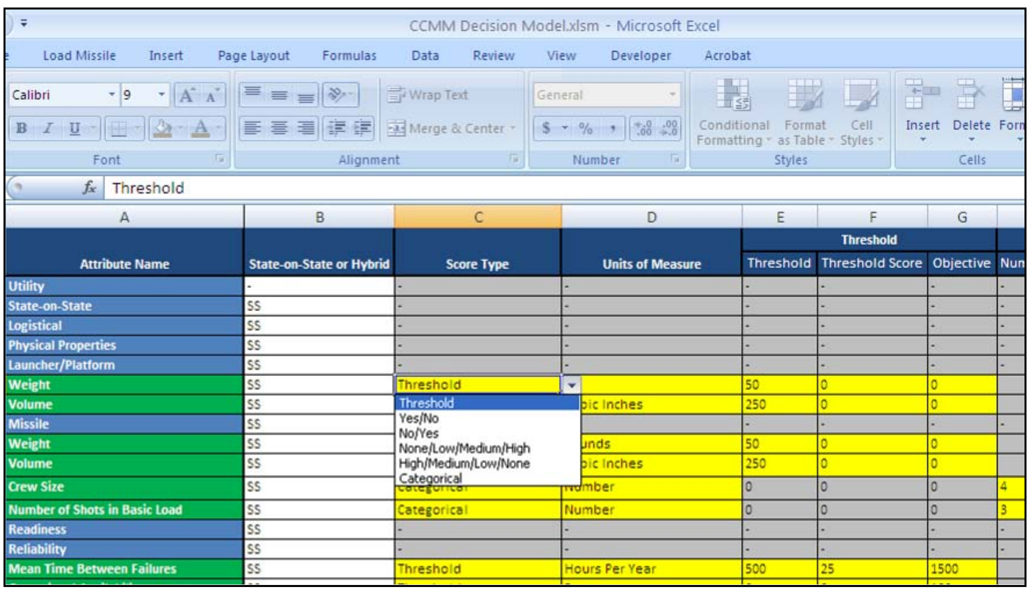


Figure E-9. Selecting a Threshold Score Type

While units of measure are not required for the model to calculate attribute scores, it is recommended that units be specified to prevent any ambiguity as users manually enter raw score values. This also ensures consistency in cases of multiple users.

Next threshold, threshold score, and objective values must be specified in the “Threshold” column. If the “Threshold,” “Threshold Score,” and “Objective” values are currently blank for the attribute, they are set to zero; otherwise, the most recently entered threshold values are displayed. To specify the threshold, enter the numerical value in the “Threshold” column underneath the “Threshold” sub-heading for the appropriate attribute. To specify the threshold score, which must be between 0 and

100, enter the desired score in the “Threshold” column underneath the “Threshold Score” sub-heading for the appropriate attribute. If a number less than zero or more than 100 is entered as the threshold score, a message box as shown in Figure E-9 will prompt the user to enter a value between 0 and 100 and the value will be reset to zero. To specify the objective, enter the value in the “Threshold” column underneath the “Objective” sub-heading for the appropriate attribute. Note that any values entered into the “Threshold,” “Threshold Score,” and “Objective” cells do not change until edited manually by the user, even when the score type is changed in the drop-down menu. However, these cells will only be available for editing when the Threshold score type is selected as the score type of choice for the attribute.

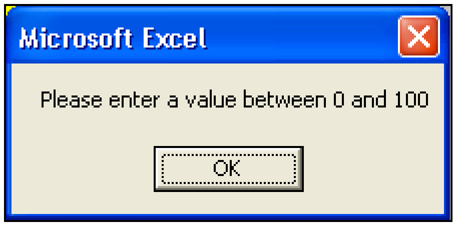
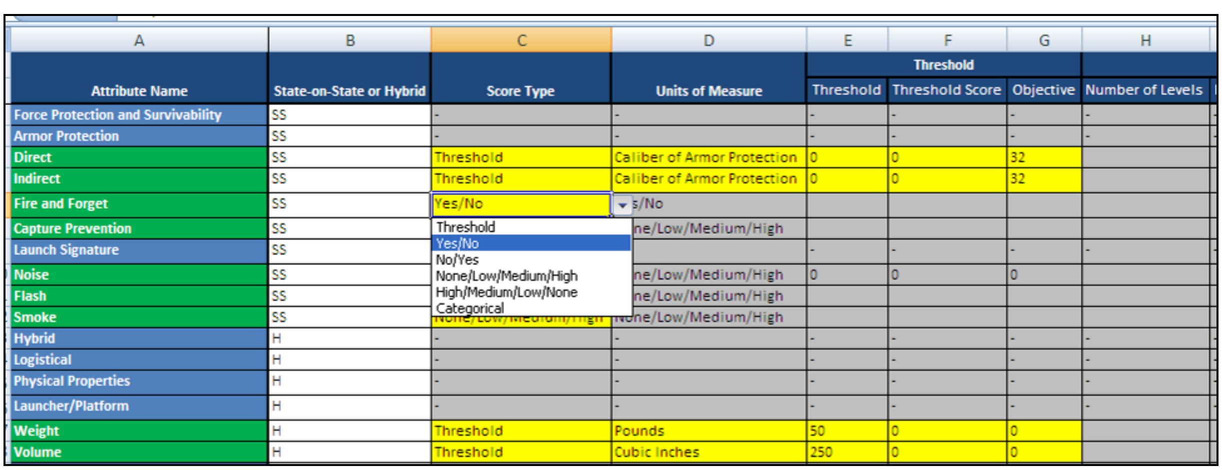


Figure E-10. The Invalid Threshold Score Message Box

E.3.4.2 Yes/No and No/Yes Score Type

The Yes/No score type should be assigned to attributes that are yes/no in nature and for which a “Yes” characterization is the desired characterization. Attributes receiving a “Yes” characterization receive a score of 100 while attributes receiving a “No” characterization receive a score of zero. For example, the user may wish to score “All-Terrain” as a “Yes/No” score type where CCMs that are all-terrain capable, receive a “Yes” response, and receive the maximum score of 100. To specify a Yes/No score type for an attribute, select “Yes/No” from the drop-down menu of the “Score Type” column for the appropriate attribute as shown in Figure E-11. Once “Yes/No” has been selected from the drop-down menu the cells under the “Units of Measure,” “Threshold” and “Enumeration” columns are grayed out and locked indicating these values are not required to calculate the score for the attribute. The units of measure for the attribute are automatically set to “Yes/No.” The grayed out columns are not available for editing unless Threshold or Enumeration respectively is chosen as the score type for the attribute.



A	B	C	D	E	F	G	H
				Threshold			
Attribute Name	State-on-State or Hybrid	Score Type	Units of Measure	Threshold	Threshold Score	Objective	Number of Levels
Force Protection and Survivability	SS	-	-	-	-	-	-
Armor Protection	SS	-	-	-	-	-	-
Direct	SS	Threshold	Caliber of Armor Protection	0	0	32	
Indirect	SS	Threshold	Caliber of Armor Protection	0	0	32	
Fire and Forget	SS	Yes/No	s/No				
Capture Prevention	SS		ne/Low/Medium/High				
Launch Signature	SS			-	-	-	-
Noise	SS		ne/Low/Medium/High	0	0	0	
Flash	SS		ne/Low/Medium/High				
Smoke	SS		ne/Low/Medium/High				
Hybrid	H	-	-	-	-	-	-
Logistical	H	-	-	-	-	-	-
Physical Properties	H	-	-	-	-	-	-
Launcher/Platform	H	-	-	-	-	-	-
Weight	H	Threshold	Pounds	50	0	0	
Volume	H	Threshold	Cubic Inches	250	0	0	

Figure E-11. Selecting a Yes/No Score Type

The No/Yes score type should be assigned to attributes that are yes/no in nature and for which a “No” characterization is the desired characterization. Under this scoring scheme, attributes receiving a “No” characterization achieve a score of 100 while attributes receiving a “Yes” characterization achieve a score of zero. For example, the user may wish to score “Flight Path Restrictions” as a No/Yes score type where CCMs that do not possess flight path restrictions achieve a “No” characterization and receive the maximum score of 100. To specify a No/Yes score type for an attribute, select “No/Yes” from the drop-down menu of the “Score Type” column for the appropriate attribute as shown in Figure E-12. Once “No/Yes” has been selected from the drop-down menu the cells under the “Units of Measure,” “Threshold” and “Enumeration” columns are grayed out and locked indicating these values are not required to calculate the score for the attribute. The units of measure for the attribute are automatically set to “Yes/No.” The grayed out columns are not available for editing unless Threshold or Enumeration respectively is chosen as the score type for the attribute.

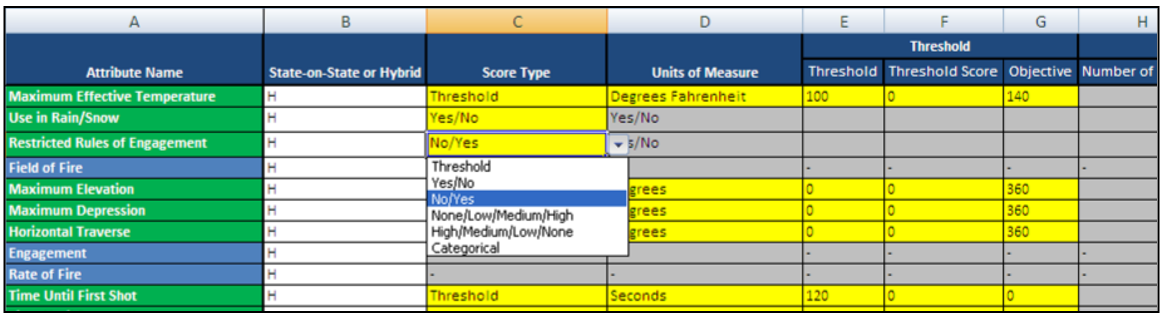


Figure E-12. Selecting a No/Yes Score Type

E.3.4.3 None/Low/Medium/High and High/Medium/Low/None Score Type

The None/Low/Medium/High and High/Medium/Low/None score types should be assigned to attributes that are qualitative in nature and cannot easily be measured quantitatively. The None/Low/Medium/High score type should be used when “None” is the most desired characterization and “High” is the least desirable characterization. Under this scoring scheme, a characterization of “None” receives a score of 100, a “Low” characterization receives a score of 66.66, a “Medium” characterization receives a score of 33.33, and a “High” characterization receives a score of zero. To specify a None/Low/Medium/High score type for an attribute, select “None/Low/Medium/High” from the drop-down menu of the “Score Type” column for the appropriate attribute as shown in Figure E-13. Once “None/Low/Medium/High” has been selected from the drop-down menu, the cells under the “Units of Measure,” “Threshold” and “Enumeration” columns are grayed out indicating these values are not required to calculate the score for the attribute. The units of measure for the attribute are automatically set to “None/Low/Medium/High.” The grayed out columns are not available for editing unless Threshold or Enumeration respectively is selected as the score type for the attribute.

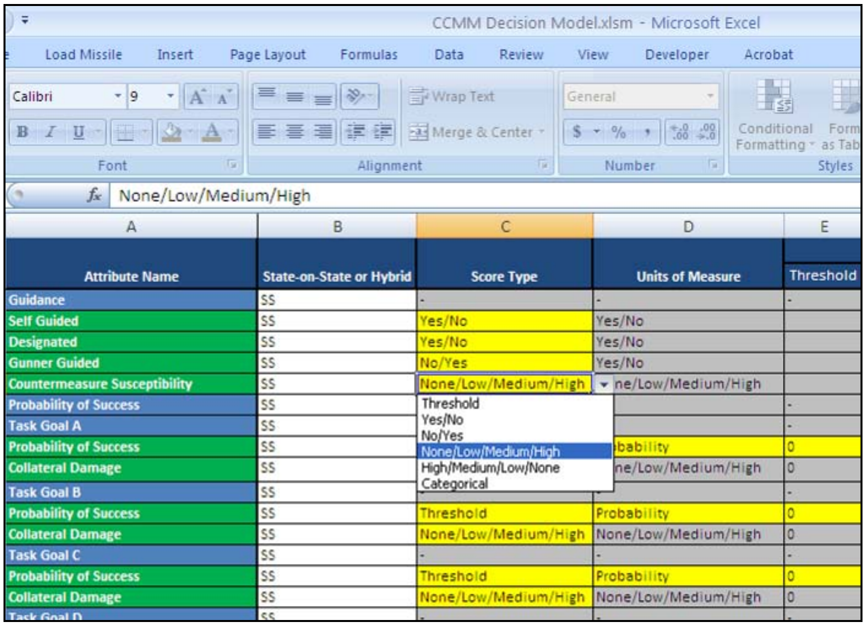
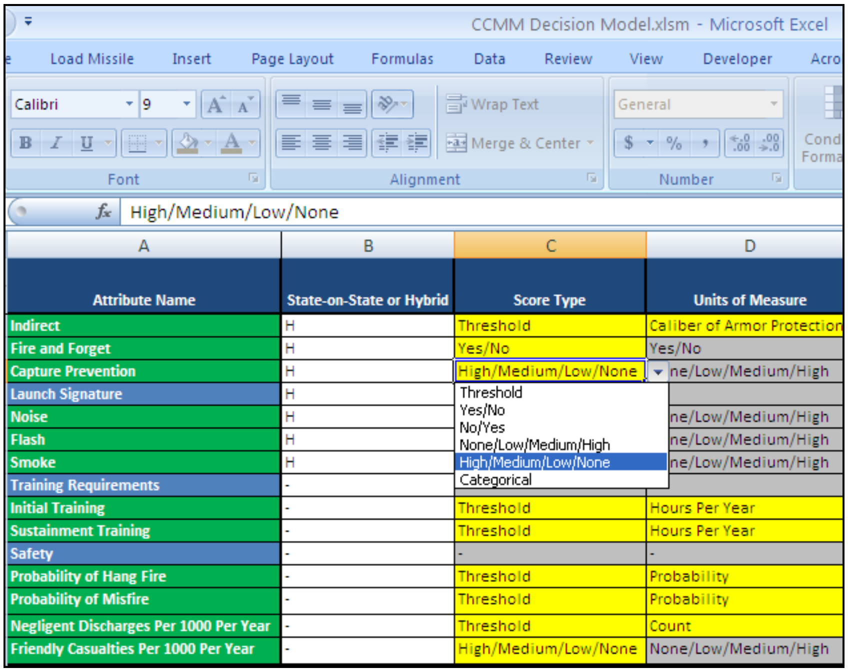


Figure E-13. Selecting a None/Low/Medium/High Score Type

The High/Medium/Low/None score type should be used when “High” is the most desired characterization and “None” is the least desirable characterization. Under this scoring scheme, a characterization of “High” receives a score of 100, a “Medium” characterization receives a score of 66.66, a “Low” characterization receives a score of 33.33, and a “None” characterization receives a score of zero. To specify a High/Medium/Low/None score type for an attribute, select “High/Medium/Low/None” from the drop-down menu of the “Score Type” column for the appropriate attribute as shown in Figure E-14. Once “High/Medium/Low/None” has been selected from the drop-down menu the cells under the “Units of Measure,” “Threshold” and “Enumeration” columns are grayed out and locked indicating these values are not required to calculate the score for the attribute. The units of measure for the attribute are automatically set to “None/Low/Medium/High.” The grayed out columns are not available for editing unless Threshold or Enumeration respectively is chosen as the score type for the attribute.



Attribute Name	State-on-State or Hybrid	Score Type	Units of Measure
Indirect	H	Threshold	Caliber of Armor Protection
Fire and Forget	H	Yes/No	Yes/No
Capture Prevention	H	High/Medium/Low/None	ne/Low/Medium/High
Launch Signature	H		
Noise	H		ne/Low/Medium/High
Flash	H		ne/Low/Medium/High
Smoke	H		ne/Low/Medium/High
Training Requirements	-		
Initial Training	-	Threshold	Hours Per Year
Sustainment Training	-	Threshold	Hours Per Year
Safety	-	-	-
Probability of Hang Fire	-	Threshold	Probability
Probability of Misfire	-	Threshold	Probability
Negligent Discharges Per 1000 Per Year	-	Threshold	Count
Friendly Casualties Per 1000 Per Year	-	High/Medium/Low/None	None/Low/Medium/High

Figure E-14. Selecting a High/Medium/Low/None Score Type

E.3.4.4 Categorical Score Type

The "Categorical" score type should be assigned to attributes that are quantitative or qualitative in nature, naturally occur on levels or are desired to be scored on levels, and do not fit the preset "None/Low/Medium/High" or "High/Medium/Low/None" construct.

For example, the user may wish to score "Crew Size" as a Categorical score type for which there is four levels representing crew sizes of one, two, three, and four or more with appropriate scores assigned to each level. As a smaller crew size is likely desirable, a crew size of one would be assigned the highest score with the assigned scores decreasing as the crew size increases.

To specify a Categorical score type, select "Categorical" from the drop-down menu of the "Score Type" column for the appropriate attribute as shown in Figure E-15. Once "Categorical" is selected from the drop-down menu, the "Units of Measure" column and the "Number of Levels" column under the "Categorical" column for that attribute is highlighted in yellow indicating the user must specify these values in order to calculate a score. If the "Number of Levels" cell is currently blank for that attribute, the cell value is set to zero. Additionally, the cells in the "Threshold" column of the attribute row are grayed out and locked indicating these values are not required to calculate the score for the attribute. As mentioned previously, values that are located in the grayed out and locked cells cannot be deleted or edited until the user selects "Threshold" as the score type of choice for the attribute.

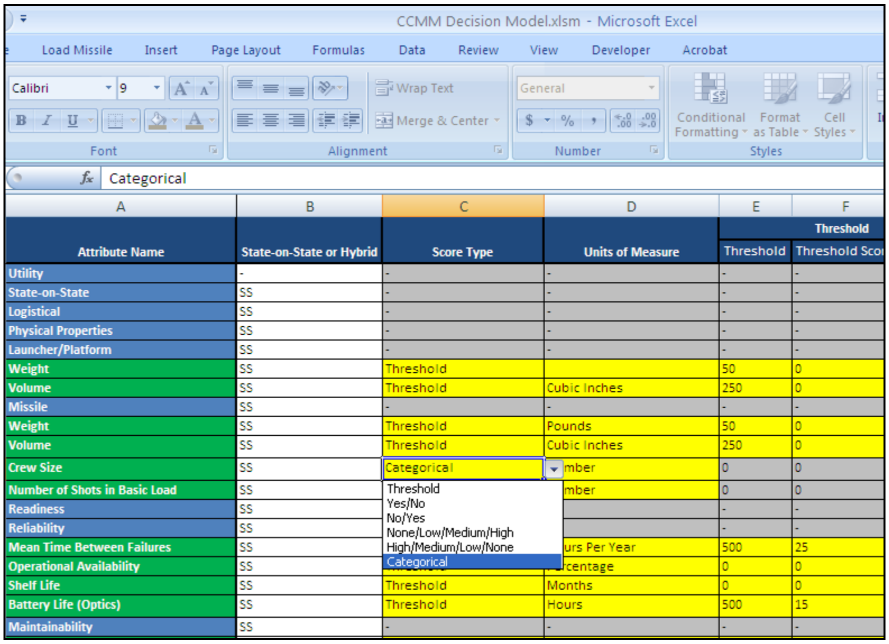


Figure E-15. Selecting a Categorical Score Type

While units of measure must not be specified for the model to calculate attribute scores, it is recommended that units be specified to prevent any ambiguity as users manually enter raw score values. This also ensures consistency in the case of multiple users.

Next, indicate the number of levels desired in the “Categorical” column underneath the “Number of Levels” sub-heading by entering an integer of at least zero but no greater than ten for the appropriate attribute. Note that a value of zero is permissible for the number of levels even though it implies that the attribute has zero enumeration levels resulting in all missiles earning a score of zero for this attribute. Thus, it is recommended that the user specify at least one level of enumeration. If a non-integer value (such as a decimal or text character) is entered for the number of categorical levels, a message box (shown in Figure E-16) will appear reminding the user to enter an integer from 0 to 10 and the “Number of Levels” value will be reset to zero.

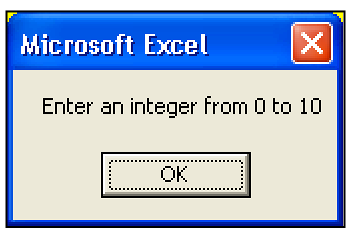
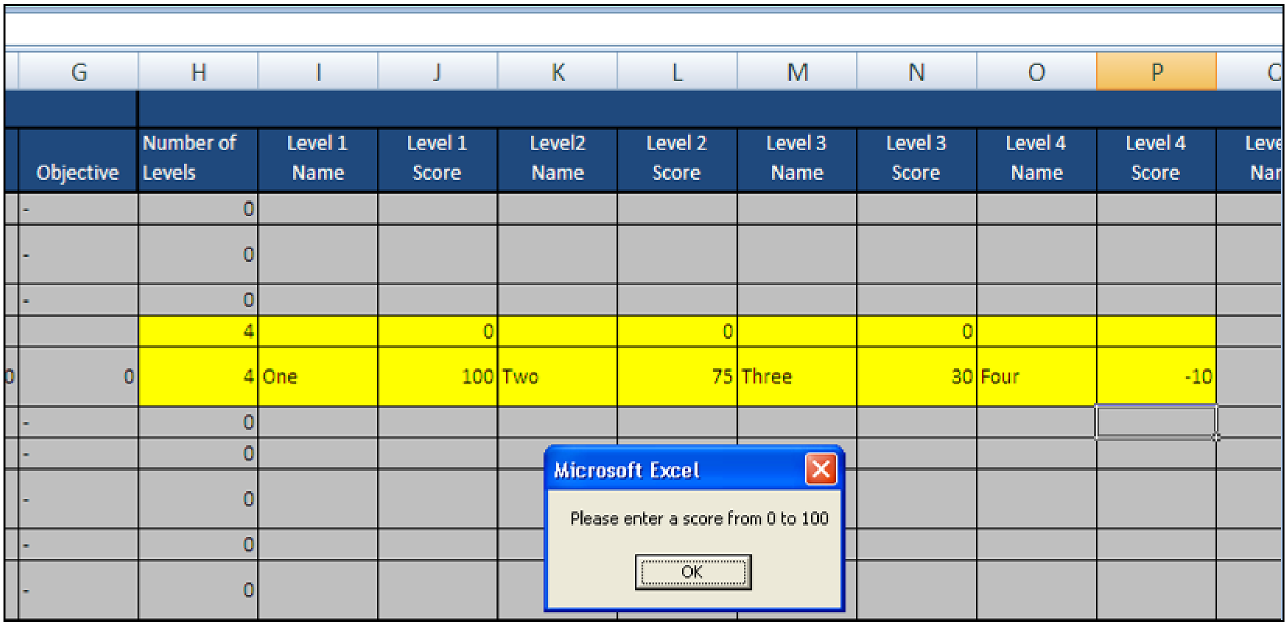


Figure E-16. Invalid Number of Levels Message Box

Once the “Number of Levels” is entered, two cells for each indicated level under the “Categorical” column are highlighted in yellow. For each level, enter a level name in the “Level Name” column for the attribute and a level score in the “Level Score” column for the attribute. The “Level Name” values will be linked to the “Score Input” worksheet as choices for the attribute input score, as is discussed in the next section. The “Level Score” value is the score assigned to the attribute when the respective “Level Name” is selected. All “Level Score” values for each attribute should be between 0 and 100. If the user inputs a value that does not fall into this range, a message box (shown in

Figure E-17) will appear reminding the user to input a value between 0 and 100 and the level score will be reset to zero.



G	H	I	J	K	L	M	N	O	P	Q
Objective	Number of Levels	Level 1 Name	Level 1 Score	Level2 Name	Level 2 Score	Level 3 Name	Level 3 Score	Level 4 Name	Level 4 Score	Leve Nar
-	0									
-	0									
-	0									
	4		0		0		0			
0	4	One	100	Two	75	Three	30	Four	-10	
-	0									
-	0									
-	0									
-	0									
-	0									

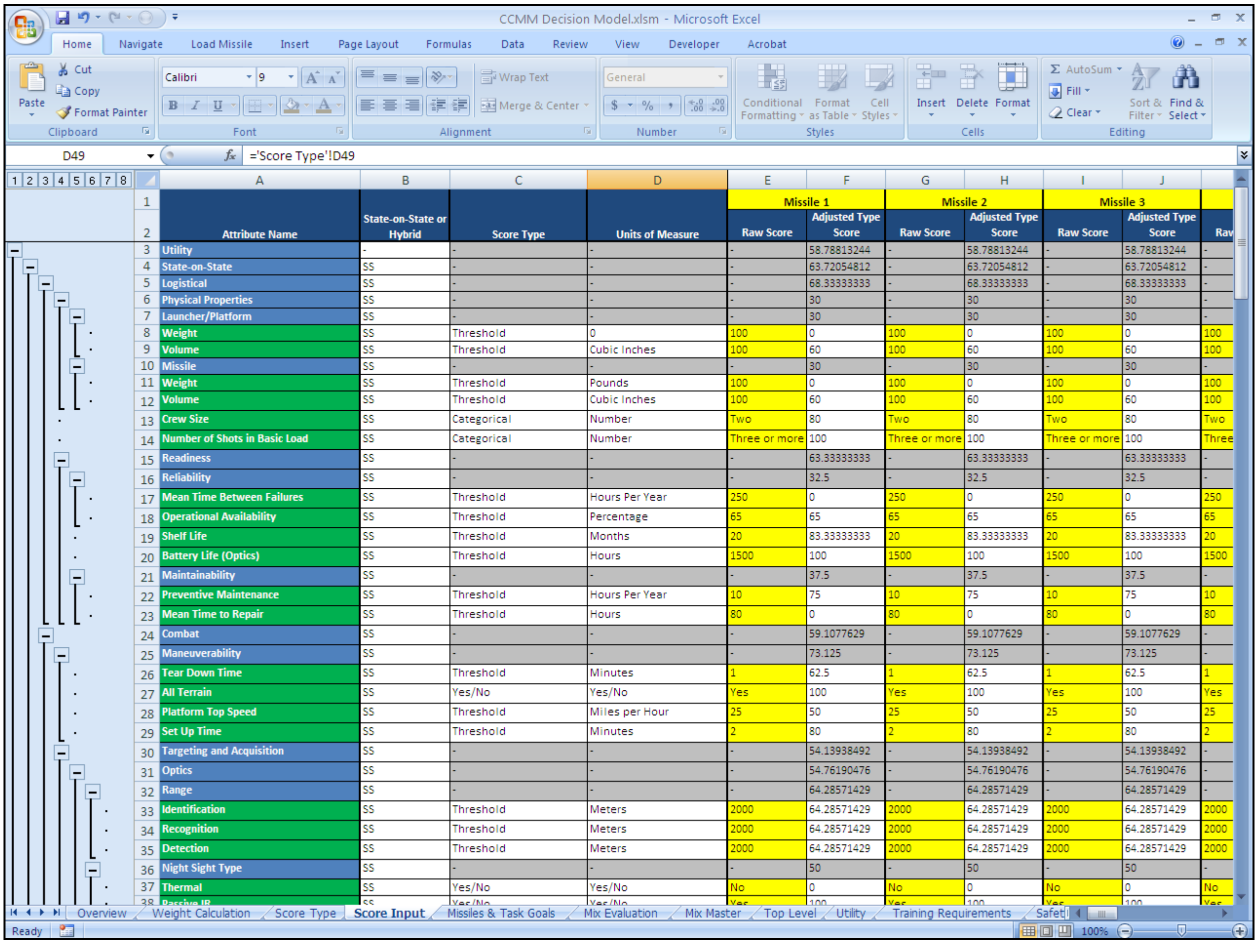
Figure E-17. Invalid Score Message Box

E.3.5 Score Input Worksheet

The Score Input worksheet shown in Figure E-18 allows users to input scores for all of the leaf attributes in order to calculate the overall DH score for missiles. The "Attributes" column lists the attributes of the CCM-DH. Leaf attributes have a green fill color while non-leaf attributes have a blue fill color. The attributes are organized in accordance with the structure of the CCM-DH with parent attributes listed above children attributes. The list of attributes can be expanded and collapsed by utilizing the two different types of outline buttons located on the far left of the worksheet. Across the top of the blue outline, section of the worksheet is a row of buttons labeled one through eight. These buttons correspond to the eight levels of the CCM-DH. Clicking on a numbered button will display the attributes up to that level of the CCM-DH and hide all other attributes. Additionally, the "+" and "-" outline buttons expand and collapse individual parent attributes. Clicking on a "+" outline button for an attribute will expand the list of attributes to include the children of the attribute. Clicking on a "-" outline button for an attribute will collapse the list of attributes to hide the children of the attribute.

Because the State-on-State and Hybrid branches are identical, the "State-on-State or Hybrid" column indicates to which branch each attribute belongs. An "H" indicates that the attribute falls under the Hybrid branch while an "SS" indicates that the attribute falls under the "State-on-State" branch. The value for this indicator is left blank for attributes to which it is not applicable (i.e., Combat Capability because it appears higher in the CCM-DH than both State-on-State and Hybrid). The "Score Type" column displays the score type specified for the attribute in the "Score Type" worksheet to remind the user of the method in which the attribute score is considered. Additionally, the "Units of Measure" are displayed for each attribute, for user reference when entering scores.

Each of the "Attributes," "State-on-State or Hybrid," "Score Type," and "Units of Measure" columns is locked as these values are not input values and should not be edited or deleted by the user. Note that for non-leaf attributes the "Score Type" and "Units of Measure" cells are grayed out and locked as these values are not user specified on the "Score Type" worksheet.



Row	Attribute Name	State-on-State or Hybrid	Score Type	Units of Measure	Missile 1 Raw Score	Missile 1 Adjusted Type Score	Missile 2 Raw Score	Missile 2 Adjusted Type Score	Missile 3 Raw Score	Missile 3 Adjusted Type Score	Rav
3	Utility	-	-	-	-	58.78813244	-	58.78813244	-	58.78813244	-
4	State-on-State	SS	-	-	-	63.72054812	-	63.72054812	-	63.72054812	-
5	Logistical	SS	-	-	-	68.33333333	-	68.33333333	-	68.33333333	-
6	Physical Properties	SS	-	-	-	30	-	30	-	30	-
7	Launcher/Platform	SS	-	-	-	30	-	30	-	30	-
8	Weight	SS	Threshold	0	100	0	100	0	100	0	100
9	Volume	SS	Threshold	Cubic Inches	100	60	100	60	100	60	100
10	Missile	SS	-	-	-	30	-	30	-	30	-
11	Weight	SS	Threshold	Pounds	100	0	100	0	100	0	100
12	Volume	SS	Threshold	Cubic Inches	100	60	100	60	100	60	100
13	Crew Size	SS	Categorical	Number	Two	80	Two	80	Two	80	Two
14	Number of Shots in Basic Load	SS	Categorical	Number	Three or more	100	Three or more	100	Three or more	100	Three
15	Readiness	SS	-	-	-	63.33333333	-	63.33333333	-	63.33333333	-
16	Reliability	SS	-	-	-	32.5	-	32.5	-	32.5	-
17	Mean Time Between Failures	SS	Threshold	Hours Per Year	250	0	250	0	250	0	250
18	Operational Availability	SS	Threshold	Percentage	65	65	65	65	65	65	65
19	Shelf Life	SS	Threshold	Months	20	83.33333333	20	83.33333333	20	83.33333333	20
20	Battery Life (Optics)	SS	Threshold	Hours	1500	100	1500	100	1500	100	1500
21	Maintainability	SS	-	-	-	37.5	-	37.5	-	37.5	-
22	Preventive Maintenance	SS	Threshold	Hours Per Year	10	75	10	75	10	75	10
23	Mean Time to Repair	SS	Threshold	Hours	80	0	80	0	80	0	80
24	Combat	SS	-	-	-	59.1077629	-	59.1077629	-	59.1077629	-
25	Maneuverability	SS	-	-	-	73.125	-	73.125	-	73.125	-
26	Tear Down Time	SS	Threshold	Minutes	1	62.5	1	62.5	1	62.5	1
27	All Terrain	SS	Yes/No	Yes/No	Yes	100	Yes	100	Yes	100	Yes
28	Platform Top Speed	SS	Threshold	Miles per Hour	25	50	25	50	25	50	25
29	Set Up Time	SS	Threshold	Minutes	2	80	2	80	2	80	2
30	Targeting and Acquisition	SS	-	-	-	54.13938492	-	54.13938492	-	54.13938492	-
31	Optics	SS	-	-	-	54.76190476	-	54.76190476	-	54.76190476	-
32	Range	SS	-	-	-	64.28571429	-	64.28571429	-	64.28571429	-
33	Identification	SS	Threshold	Meters	2000	64.28571429	2000	64.28571429	2000	64.28571429	2000
34	Recognition	SS	Threshold	Meters	2000	64.28571429	2000	64.28571429	2000	64.28571429	2000
35	Detection	SS	Threshold	Meters	2000	64.28571429	2000	64.28571429	2000	64.28571429	2000
36	Night Sight Type	SS	-	-	-	50	-	50	-	50	-
37	Thermal	SS	Yes/No	Yes/No	No	0	No	0	No	0	No
38	Passive IR	SS	Yes/No	Yes/No	Yes	100	Yes	100	Yes	100	Yes

Figure E-18. The "Score Input" Worksheet

Following these columns are forty columns allocated for score input for up to twenty different missiles. The user can name the missile to be scored in the column header cell highlighted in yellow. Each missile column is divided into two sub-columns, "Raw Score" and "Adjusted Type Score." For non-leaf attributes, the "Raw Score" are grayed out and locked, as these scores are not manually entered by the user. The "Raw Score" cells for leaf attributes are highlighted in yellow to indicate that user input is required in order to calculate the "Adjusted Type Score."

To specify a raw score of an attribute with a Threshold score type, enter a numeric value in the "Raw Score" column of the appropriate attribute. To reference the threshold, threshold score, and objective values specified on the "Score Type" worksheet, double-click the name of the attribute. When the attribute name is clicked, a chart appears that displays the linear score scale defined for the attribute appears and shows the adjusted raw score values for input values between the threshold and objective. Figure E-19 shows the linear score scale for "Probability of Hang Fire." Click anywhere on the chart to close it.

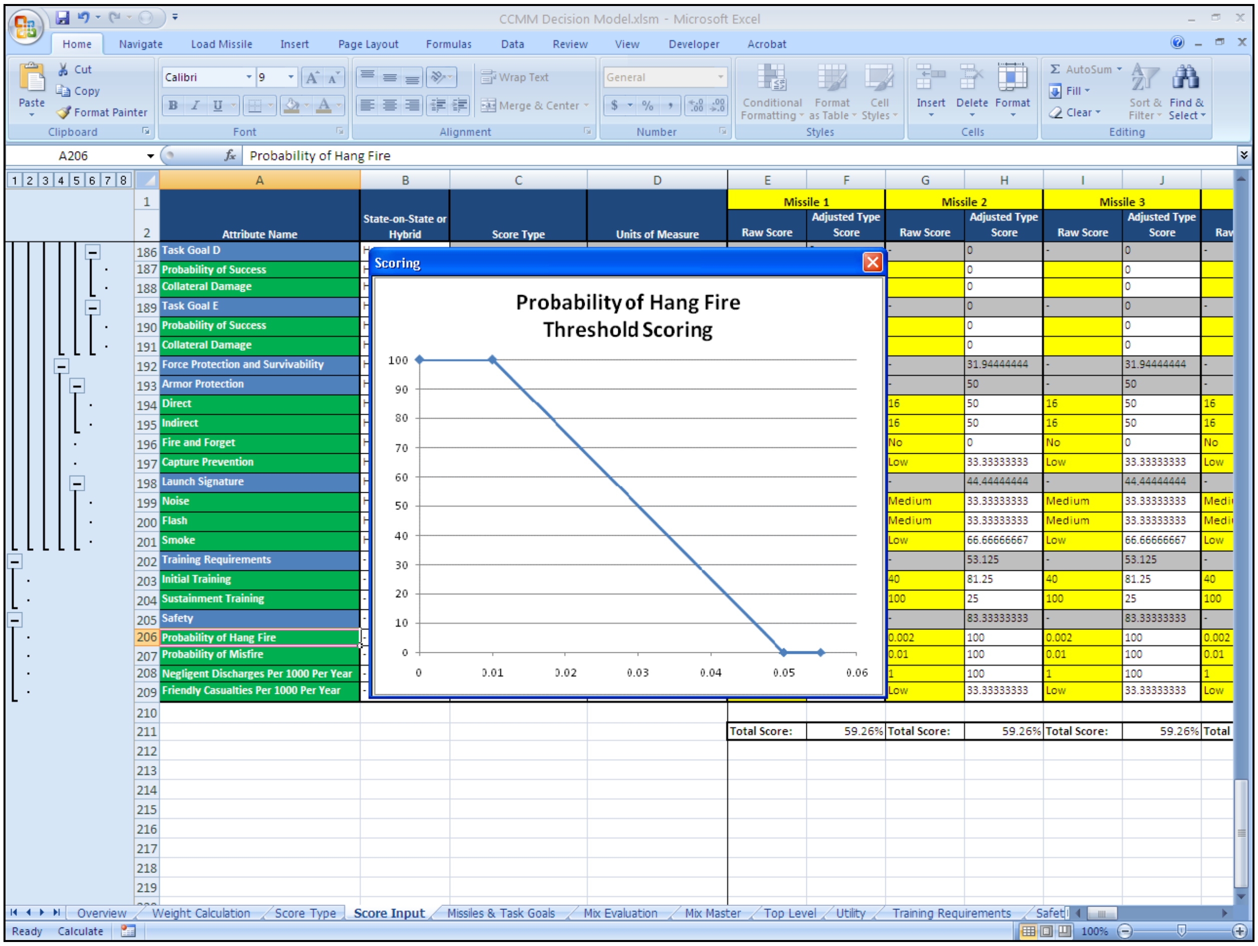


Figure E-19. Linear Score Chart for "Probability of Hang Fire"

For an attribute with a Yes/No score type, the "Raw Score" column is a drop-down menu providing the user with the choice of "Yes" or "No" for the raw score. To specify the raw score for a Yes/No score type, select "Yes" or "No" from the "Raw Score" column for the appropriate attribute.

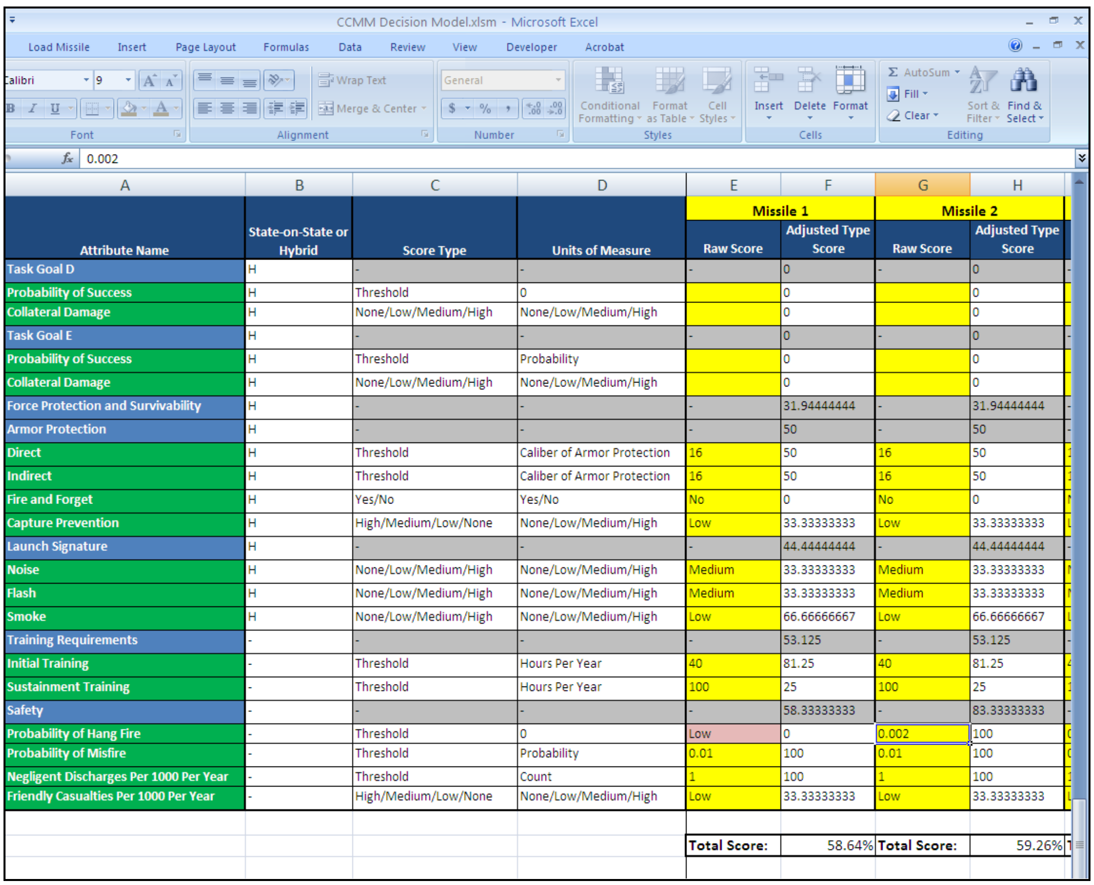
For an attribute with a No/Yes score type, the "Raw Score" column is a drop-down menu providing the user with the choice of "Yes" or "No" for the raw score. To specify the raw score for a "No/Yes" score type, select "Yes" or "No" from the "Raw Score" column for the appropriate attribute.

For an attribute with a None/Low/Medium/High score type, the "Raw Score" column is a drop-down menu providing the user with the choice of "None," "Low," "Medium," or "High" for the raw score. To specify the raw score for an attribute with a None/Low/Medium/High score type, select "None," "Low," "Medium," or "High" from the "Raw Score" column for the appropriate attribute.

For an attribute with a High/Low/Medium/None score type, the "Raw Score" column is a drop-down menu providing the user with the choice of "None," "Low," "Medium," or "High" for the raw score. To specify the raw score for an attribute with a High/Medium/Low/None score type, select "None," "Low," "Medium," or "High" from the "Raw Score" column for the appropriate attribute.

For an attribute with an Enumeration score type, the “Raw Score” is a drop-down menu providing with the user with the choice of level names specified for the attribute on the “Score Type” worksheet. To specify the raw score for an attribute with an Enumeration score type, select the appropriate level name from the provided drop-down menu.

When the “Score Type” value is changed in the “Score Type” worksheet, then the previously entered “Raw Score” value for the corresponding attribute in the “Score Input” worksheet may no longer be valid. For example, suppose the “Probability of Hang Fire” attribute is originally set as a “None/Low/Medium/High” score type on the “Score Type” worksheet and the user sets the “Missile 1” raw score to “Low” for the Probability of Hang Fire.” Then suppose the user decides that “Probability of Hang Fire” should be a threshold score type so the “Score Type” is then changed to “Threshold” on the “Score Type” worksheet. Now the “Low” value previously entered for “Probability of Hang Fire” is no longer valid. In cases like this, invalid “Raw Score” entries are highlighted in pink indicating these values are invalid and should be changed. Until the user manually changes these values, all invalid “Raw Score” entries are assigned an “Adjusted Score Type” value of zero. Figure E-20 shows an invalid “Raw Score” entry for “Probability of Hang Fire” highlighted in pink.



Attribute Name	State-on-State or Hybrid	Score Type	Units of Measure	Missile 1 Raw Score	Missile 1 Adjusted Type Score	Missile 2 Raw Score	Missile 2 Adjusted Type Score
Task Goal D	H	-	-	-	0	-	0
Probability of Success	H	Threshold	0		0		0
Collateral Damage	H	None/Low/Medium/High	None/Low/Medium/High		0		0
Task Goal E	H	-	-	-	0	-	0
Probability of Success	H	Threshold	Probability		0		0
Collateral Damage	H	None/Low/Medium/High	None/Low/Medium/High		0		0
Force Protection and Survivability	H	-	-	-	31.94444444	-	31.94444444
Armor Protection	H	-	-	-	50	-	50
Direct	H	Threshold	Caliber of Armor Protection	16	50	16	50
Indirect	H	Threshold	Caliber of Armor Protection	16	50	16	50
Fire and Forget	H	Yes/No	Yes/No	No	0	No	0
Capture Prevention	H	High/Medium/Low/None	None/Low/Medium/High	Low	33.33333333	Low	33.33333333
Launch Signature	H	-	-	-	44.44444444	-	44.44444444
Noise	H	None/Low/Medium/High	None/Low/Medium/High	Medium	33.33333333	Medium	33.33333333
Flash	H	None/Low/Medium/High	None/Low/Medium/High	Medium	33.33333333	Medium	33.33333333
Smoke	H	None/Low/Medium/High	None/Low/Medium/High	Low	66.66666667	Low	66.66666667
Training Requirements	-	-	-	-	53.125	-	53.125
Initial Training	-	Threshold	Hours Per Year	40	81.25	40	81.25
Sustainment Training	-	Threshold	Hours Per Year	100	25	100	25
Safety	-	-	-	-	58.33333333	-	83.33333333
Probability of Hang Fire	-	Threshold	0	Low	0	0.002	100
Probability of Misfire	-	Threshold	Probability	0.01	100	0.01	100
Negligent Discharges Per 1000 Per Year	-	Threshold	Count	1	100	1	100
Friendly Casualties Per 1000 Per Year	-	High/Medium/Low/None	None/Low/Medium/High	Low	33.33333333	Low	33.33333333
				Total Score:	58.64%	Total Score:	59.26%

Figure E-20. “Raw Score” Entry Validation Highlight

The “Adjusted Type Score” column is locked as this is automatically calculated by applying the score type scoring scheme specified for the attribute on the “Score Input” worksheet to the raw score. The total score for each missile is displayed at the bottom of the missile column and is labeled “Total Score” as shown in Figure E-21. The total

score is the official CCM-DH score for the missile and is displayed as a percentage out of 100.

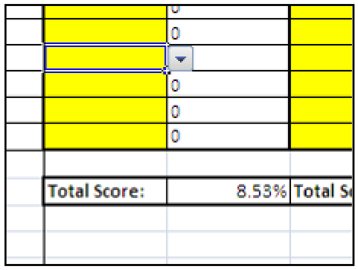
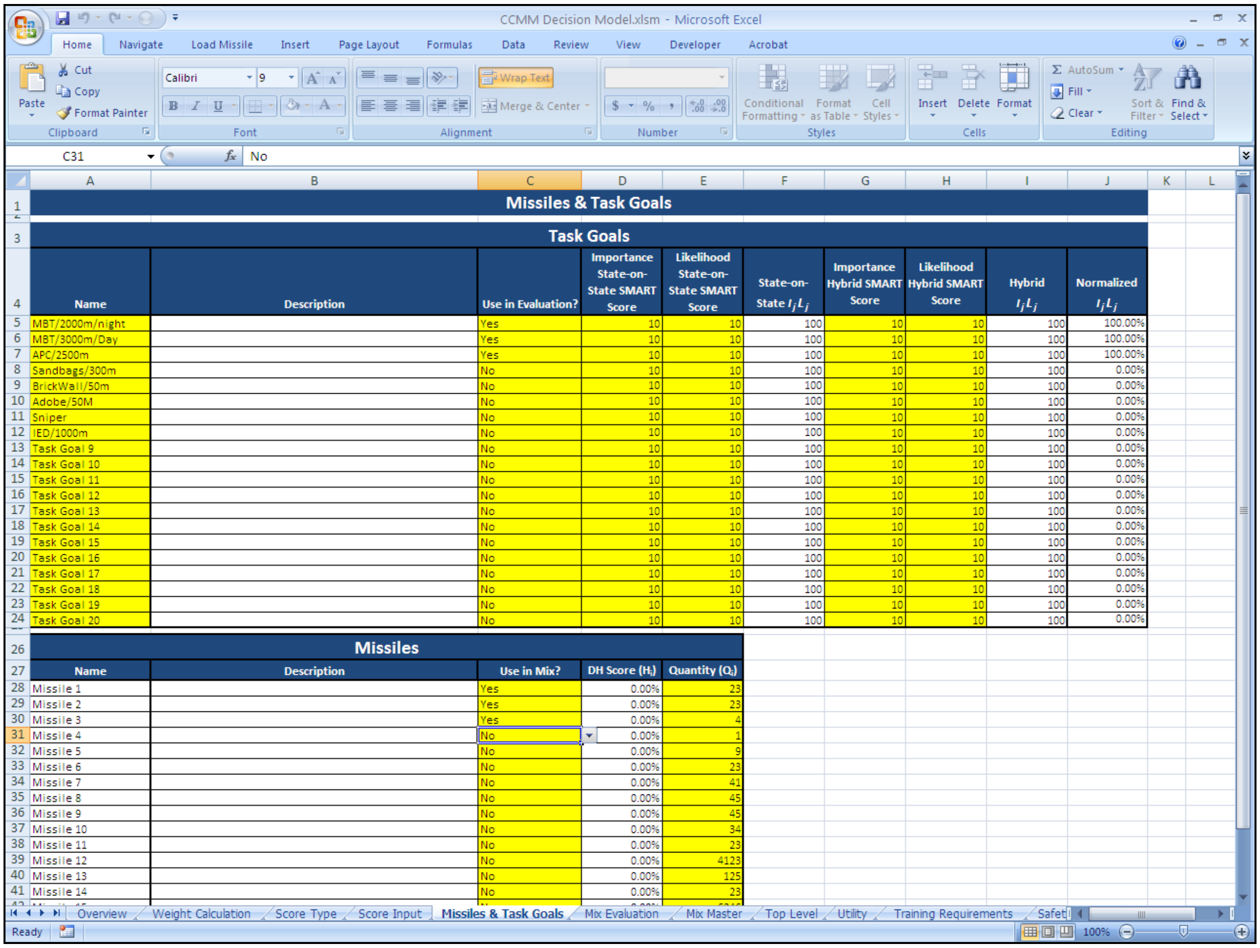


Figure E-21. The Total Score for a Missile from the "Score Input" Worksheet

E.3.6 Missiles & Task Goals Worksheet

The "Missiles & Task Goals" worksheet shown in Figure E-22 allows the user to enter information about the missiles and task goals to be included in a missile mix for evaluation. The "Missiles & Task Goals" worksheet is divided into two tables, one devoted to missile information and one devoted to task goal information. A valid missile mix must consist of at least one missile and one task goal.



Missiles & Task Goals

Task Goals

Name	Description	Use in Evaluation?	Importance State-on-State SMART Score	Likelihood State-on-State SMART Score	State-on-State $I_j L_j$	Importance Hybrid SMART Score	Likelihood Hybrid SMART Score	Hybrid $I_j L_j$	Normalized $I_j L_j$
MBT/2000m/night		Yes	10	10	100	10	10	100	100.00%
MBT/3000m/Day		Yes	10	10	100	10	10	100	100.00%
APC/2500m		Yes	10	10	100	10	10	100	100.00%
Sandbags/300m		No	10	10	100	10	10	100	0.00%
BrickWall/50m		No	10	10	100	10	10	100	0.00%
Adobe/50M		No	10	10	100	10	10	100	0.00%
Sniper		No	10	10	100	10	10	100	0.00%
IED/1000m		No	10	10	100	10	10	100	0.00%
Task Goal 9		No	10	10	100	10	10	100	0.00%
Task Goal 10		No	10	10	100	10	10	100	0.00%
Task Goal 11		No	10	10	100	10	10	100	0.00%
Task Goal 12		No	10	10	100	10	10	100	0.00%
Task Goal 13		No	10	10	100	10	10	100	0.00%
Task Goal 14		No	10	10	100	10	10	100	0.00%
Task Goal 15		No	10	10	100	10	10	100	0.00%
Task Goal 16		No	10	10	100	10	10	100	0.00%
Task Goal 17		No	10	10	100	10	10	100	0.00%
Task Goal 18		No	10	10	100	10	10	100	0.00%
Task Goal 19		No	10	10	100	10	10	100	0.00%
Task Goal 20		No	10	10	100	10	10	100	0.00%

Missiles

Name	Description	Use in Mix?	DH Score (H_i)	Quantity (Q_i)
Missile 1		Yes	0.00%	23
Missile 2		Yes	0.00%	23
Missile 3		Yes	0.00%	4
Missile 4		No	0.00%	1
Missile 5		No	0.00%	9
Missile 6		No	0.00%	23
Missile 7		No	0.00%	41
Missile 8		No	0.00%	45
Missile 9		No	0.00%	45
Missile 10		No	0.00%	34
Missile 11		No	0.00%	23
Missile 12		No	0.00%	4123
Missile 13		No	0.00%	125
Missile 14		No	0.00%	23

Figure E-22. The Missiles & Task Goals Worksheet

E.3.6.1 Entering Task Goal Information

The first table that appears in the “Missiles & Task Goals” worksheet is the “Task Goals” table. All cells highlighted in yellow require user input. The first column is the “Name” column in which the name of a desired task goal must be manually entered. The CCMM Decision Model can evaluate up to 20 task goals per missile mix. To enter a task goal name, click in the desired cell within the “Name” column and type the desired task goal name. The second column is the “Description” column and allows the user to provide a brief description for a task goal. A task goal description is not required in order for the model to successfully evaluate a missile mix but it is recommended that the user provide a description to prevent ambiguity between similarly named or comparable task goals. To enter a description for a task goal, click on the desired cell inside the “Description” column and type a task goal description.

The “Use in Evaluation?” column allows the user to select task goals for inclusion in the current missile mix evaluation. This allows the user to select sets of task goals for missile mix inclusion without recreating task goal information. The “Use in Evaluation?” column also allows the user to quickly and easily perform sensitivity analysis by comparing mix scores between missile mixes with similar or even dissimilar task goals. To include a listed task goal in the current missile mix, select “Yes” from the drop-down menu provided in the appropriate task goal row under the “Use in Evaluation?” column as shown in Figure E-23. To exclude a task goal from the current missile mix, select “No” from the drop-down menu provided in the appropriate task goal row under the “Use in Evaluation?” column.

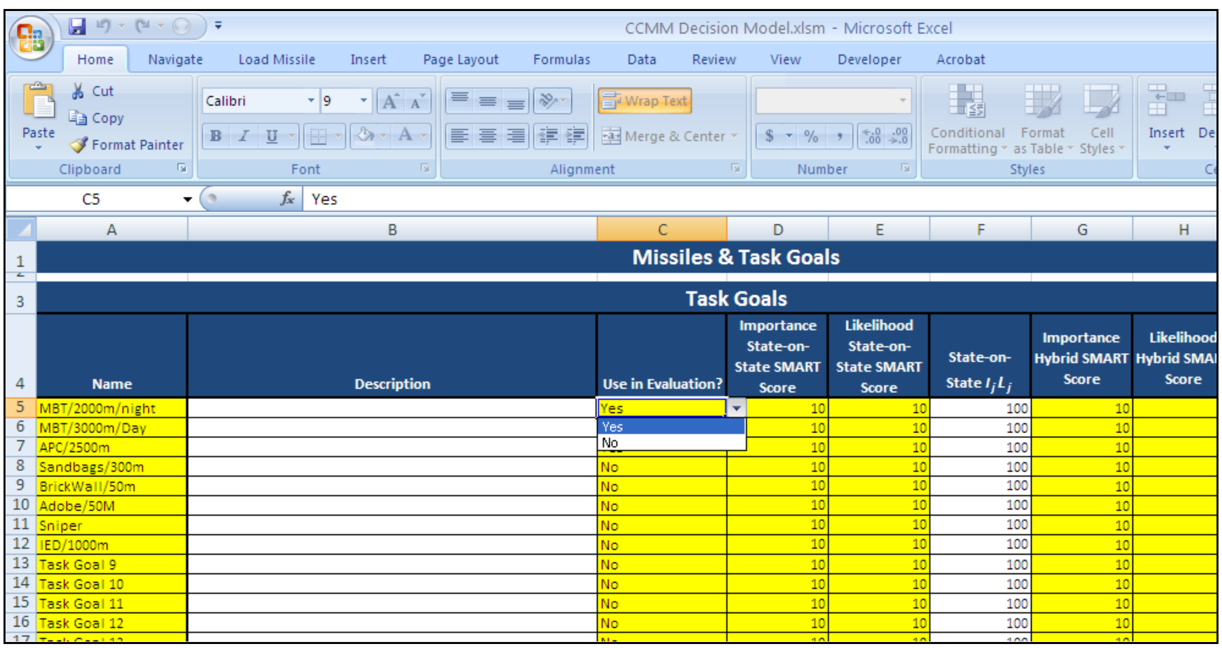


Figure E-23. Including a Task Goal in the Mix Evaluation

The “Importance State-on-State SMART Score,” “Likelihood State-on-State SMART Score,” and “State-on-State I_jL_j” columns allow the user to assign a state-on-state importance and likelihood value to each task goal. Since the importance and likelihood of task goals may depend on the type of warfare in which they are considered (i.e., state-on-state versus hybrid) the CCMM Decision Model calculates the overall risk of a

task goal in state-on-state warfare by multiplying its state-on-state importance and likelihood SMART scores. The state-on-state risk of each task goal given in column “State-on-State I_jL_j” is automatically updated whenever a new task goal is added to or removed from the missile mix or any state-on-state importance or likelihood value for a task goal under consideration is changed.

To enter a state-on-state SMART importance score for a task goal, click in the “Importance State-on-State SMART Score” column for the appropriate task goal and enter a value of at least ten. (Note that SMART evaluation is conducted by assigning a value of ten to the least important item under consideration and then assigning values of ten or greater to the remaining items based on their importance when compared to the least important item. To exclude a task goal from consideration, change its “Use in Evaluation?” value to “No” instead of assigning it a SMART value of zero). If a non-numeric value, or numeric value less than ten, is entered into either column, a message box (shown in Figure E-24) will appear prompting the user to enter a value of at least ten. To enter a state-on-state SMART likelihood score for a task goal, click in the “Likelihood State-on-State SMART Score” column for the appropriate task goal and enter a value of at least ten.

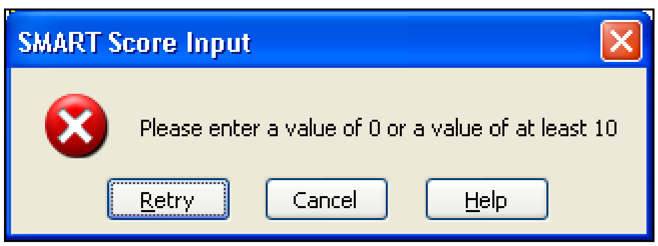


Figure E-24. The Invalid SMART Score Message Box

The “Importance Hybrid SMART Score,” “Likelihood Hybrid SMART Score,” and “Hybrid I_jL_j” columns allow the user to assign a hybrid importance and likelihood value to each task goal. Since the importance and likelihood of task goals may depend on the type of warfare in which they are considered (i.e., state-on-state versus hybrid) the CCMM Decision Model calculates the overall risk of a task goal in hybrid warfare by multiplying its hybrid importance and likelihood SMART scores. The hybrid risk of each task goal is automatically updated in column “Hybrid I_jL_j” whenever a new task goal is added to or removed from the missile mix or any hybrid importance or likelihood value for a task goal under consideration is changed.

To enter an importance SMART hybrid score for a task goal, click in the “Importance Hybrid SMART Score” column for the appropriate task goal and enter a value of at least ten. To enter a hybrid SMART likelihood score for a task, click in the “Likelihood Hybrid SMART Score” column for the appropriate task goal and enter a value of at least ten. If a non-numeric value, or numeric value less than ten, is entered into either a column, a message box will appear prompting the user to enter a value of at least ten.

The “Normalized I_jL_j” column will automatically calculate the normalized risk of each task goal by combining the weighted sum of the “State-on-State I_jL_j” and “Hybrid I_jL_j” values with the riskiest task goal achieving a normalized risk of 100%. The relative weight of state-on-state warfare to hybrid warfare is taken from the relative weights assigned on the “Weight Calculation” worksheet. The “Normalized I_jL_j” column is locked as it contains formulas that should not be edited or deleted by the user.

E.3.6.2 Entering Missile Information

The “Missiles” table appears below the “Task Goals” table in the “Missiles & Task Goals” worksheet and allows users to enter information for the missiles of a missile mix. All cells highlighted in yellow require user input. The “Name” column displays the name of the missile and is automatically populated by the missile names assigned on the “Score Input” worksheet. Because the model can only evaluate missile mixes consisting of missiles for which a DH value (H_i) (which corresponds the missile total score from the “Score Input” worksheet) has been calculated, only those missiles from the “Score Input” worksheet can be considered. Thus, the user must ensure that any missiles to be included in the mix evaluation are first individually scored on the “Score Input” worksheet. The missile “Name” column is locked as it is automatically updated from the “Score Input” worksheet and may not be edited or deleted by the user.

The “Description” column allows the user to provide a brief description for a missile. A missile description is not required in order for the model to successfully evaluate a missile mix but it is recommended that the user provide a description to prevent ambiguity between similarly named or comparable missiles. To enter a description for a missile, click inside the “Description” column for the appropriate missile and type the missile description.

The “Use in Mix?” column allows the user to select missiles for inclusion in the current missile mix evaluation. This allows the user to select sets of missiles for missile mix inclusion without recreating missile information. Also, the “Use in Mix?” column allows the user to quickly and easily perform sensitivity analysis by comparing scores between mixes with different missile combinations. To include a listed missile in the current missile mix, select “Yes” from the drop-down menu provided in “Use in Mix?” column for the desired missile. To exclude a missile from the current missile mix, select “No” from the drop-down menu provided in the “Use in Mix?” column for the desired missile.

As mentioned above, only missiles for which a DH (H_i) score has been calculated can be evaluated in a missile mix. The “DH Score (H_i)” column displays the DH (H_i) score for each missile and is automatically populated by the DH (H_i) score calculated in the “Score Input” worksheet in the cell titled “Total” for each missile. The DH Score (H_i) is displayed as a percentage out of 100. The “DH Score (H_i)” column is locked as users should not edit or delete these values.

The “Quantity (Q_i)” column allows the user to input the quantity of each missile type available in the current missile mix. To enter a quantity for a given missile, click inside “Quantity (Q_i)” column for the appropriate missile and enter a value of at least zero. If a non-numeric value or a value less than zero is entered, a message box (shown in Figure E-25) will appear prompting the user to enter a value of at least zero.

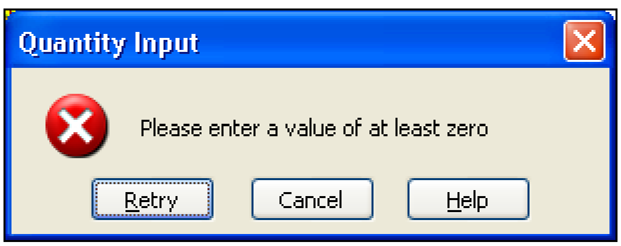
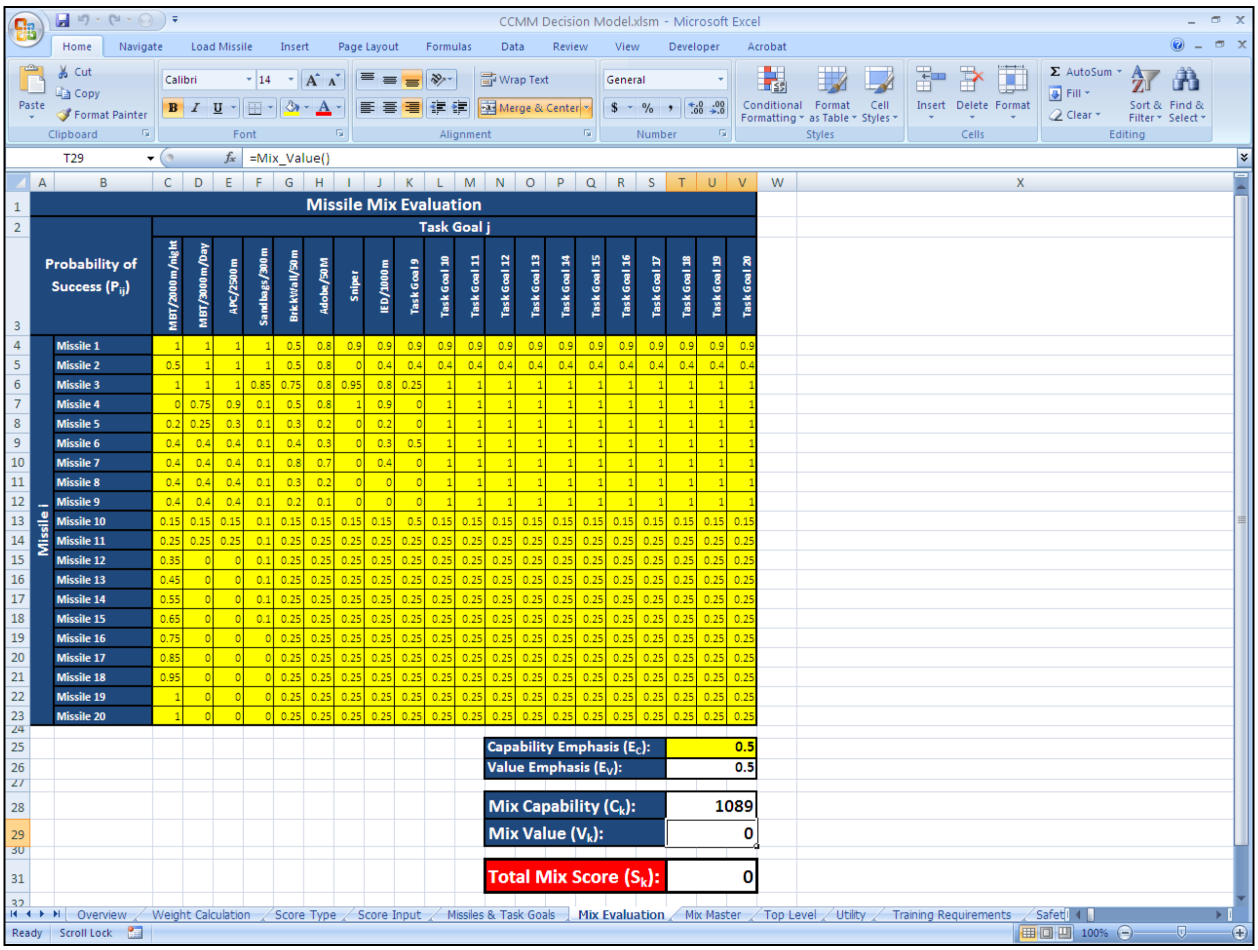


Figure E-25. The Invalid Missile Quantity Message Box

E.3.7 Mix Evaluation Worksheet

The “Mix Evaluation” worksheet shown in Figure E-26 allows the user to enter probabilities of success for each missile-task goal combination and evaluates the current missile mix as defined by its missile and task goal values specified on the “Missiles & Task Goals” worksheet. The “Mix Evaluation” table displays the probability of success for each missile against each task goal. All probability cells are highlighted in yellow indicating user input is required. In the table, the task goals are listed across the top of each column while the missile names are listed to the left along each row. The missile and task goal names are automatically populated with the missile and task goal names from the “Missiles & Task Goals” worksheet. The headers of each row and column are locked as these are not to be edited or deleted by the user. The probability of missile *i* accomplishing task goal *j* is given by the probability entered into the cell in the missile *i* row of task goal column *j*. The probability of success is not only meant to capture the probability of success of missile *i* completing task goal *j*, but is also meant to capture the feasibility and practicality of the missile completing the task goal in general. In other words, if missile *i* will never be used to accomplish task goal *j* due to certain rules of engagement restrictions or because of impracticality/unsuitability of the missile for the task goal, the probability of success should be set to zero.



Probability of Success (P_{ij})	MBT/2000m/night	MBT/3000m/Day	APC/2500m	Sandbags/300m	BrickWall/50m	Adobe/50M	Sniper	IED/1000m	Task Goal 9	Task Goal 10	Task Goal 11	Task Goal 12	Task Goal 13	Task Goal 14	Task Goal 15	Task Goal 16	Task Goal 17	Task Goal 18	Task Goal 19	Task Goal 20
Missile 1	1	1	1	1	0.5	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Missile 2	0.5	1	1	1	0.5	0.8	0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Missile 3	1	1	1	0.85	0.75	0.8	0.95	0.8	0.25	1	1	1	1	1	1	1	1	1	1	1
Missile 4	0	0.75	0.9	0.1	0.5	0.8	1	0.9	0	1	1	1	1	1	1	1	1	1	1	1
Missile 5	0.2	0.25	0.3	0.1	0.3	0.2	0	0.2	0	1	1	1	1	1	1	1	1	1	1	1
Missile 6	0.4	0.4	0.4	0.1	0.4	0.3	0	0.3	0.5	1	1	1	1	1	1	1	1	1	1	1
Missile 7	0.4	0.4	0.4	0.1	0.8	0.7	0	0.4	0	1	1	1	1	1	1	1	1	1	1	1
Missile 8	0.4	0.4	0.4	0.1	0.3	0.2	0	0	0	1	1	1	1	1	1	1	1	1	1	1
Missile 9	0.4	0.4	0.4	0.1	0.2	0.1	0	0	0	1	1	1	1	1	1	1	1	1	1	1
Missile 10	0.15	0.15	0.15	0.1	0.15	0.15	0.15	0.15	0.5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Missile 11	0.25	0.25	0.25	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 12	0.35	0	0	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 13	0.45	0	0	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 14	0.55	0	0	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 15	0.65	0	0	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 16	0.75	0	0	0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 17	0.85	0	0	0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 18	0.95	0	0	0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 19	1	0	0	0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Missile 20	1	0	0	0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

Figure E-26. The “Mix Evaluation” Worksheet

To enter a probability for a missile/task goal combination, click inside the cell corresponding to the row of the missile and the column of the corresponding task goal

and enter a value from zero to one. If a non-numeric value or a numeric value less than zero or more than one is entered, a message box (shown in Figure E-27) will appear prompting the user to enter a value between 0 and 1 and the value will be reset to zero.

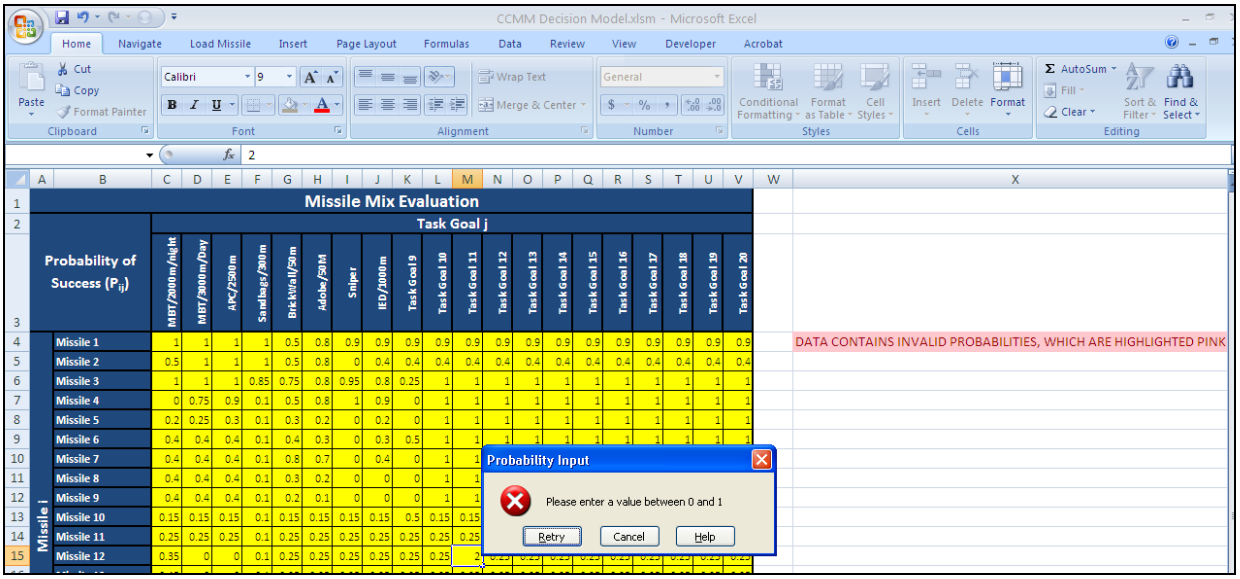


Figure E-27. Invalid Probability of Success Value

Below the probability table of the "Mix Evaluation" worksheet is a series of cells displaying missile mix evaluation values. The first cell labeled "Capability Emphasis (E_C)" is the only value cell highlighted in yellow as it is the only other value other than the probabilities table values for which user input is required. The capability emphasis is the relative emphasis of the capability versus the DH score (H_i) of a missile i and is used to determine the overall score of the mix. The capability value (C_k) of mix k represents the overall capability of mix k as calculated by the probability of success of each missile against each task goal weighted by the relative likelihood (L_j) and importance (I_j) of each task goal. The mix value (V_k) of mix k represents the overall value of a missile mix as calculated by the DH (H_i) value when considering the quantity (Q_i) of each missile included in the mix. Together, the emphasis of the capability value (C_k) and the mix value (V_k) must add to up to one. Therefore, the user is only required to input the capability emphasis; the value emphasis automatically will be calculated by subtracting the capability emphasis from one. The user is encouraged to experiment with different emphasis values to determine the sensitivity of the mix score to the relative emphasis of value vs. capability.

To enter a capability emphasis, click inside the "Capability Emphasis (E_C)"" cell highlighted in yellow and enter a value between zero and one. If a non-numeric value or a numeric value less than zero or greater than one is entered, a message box (shown in Figure E-28) will appear prompting the user to input a value between 0 and. The "Value Weight" cell is automatically updated.

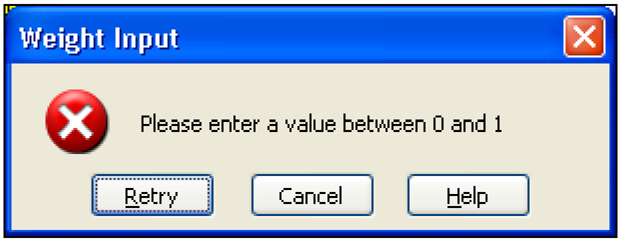


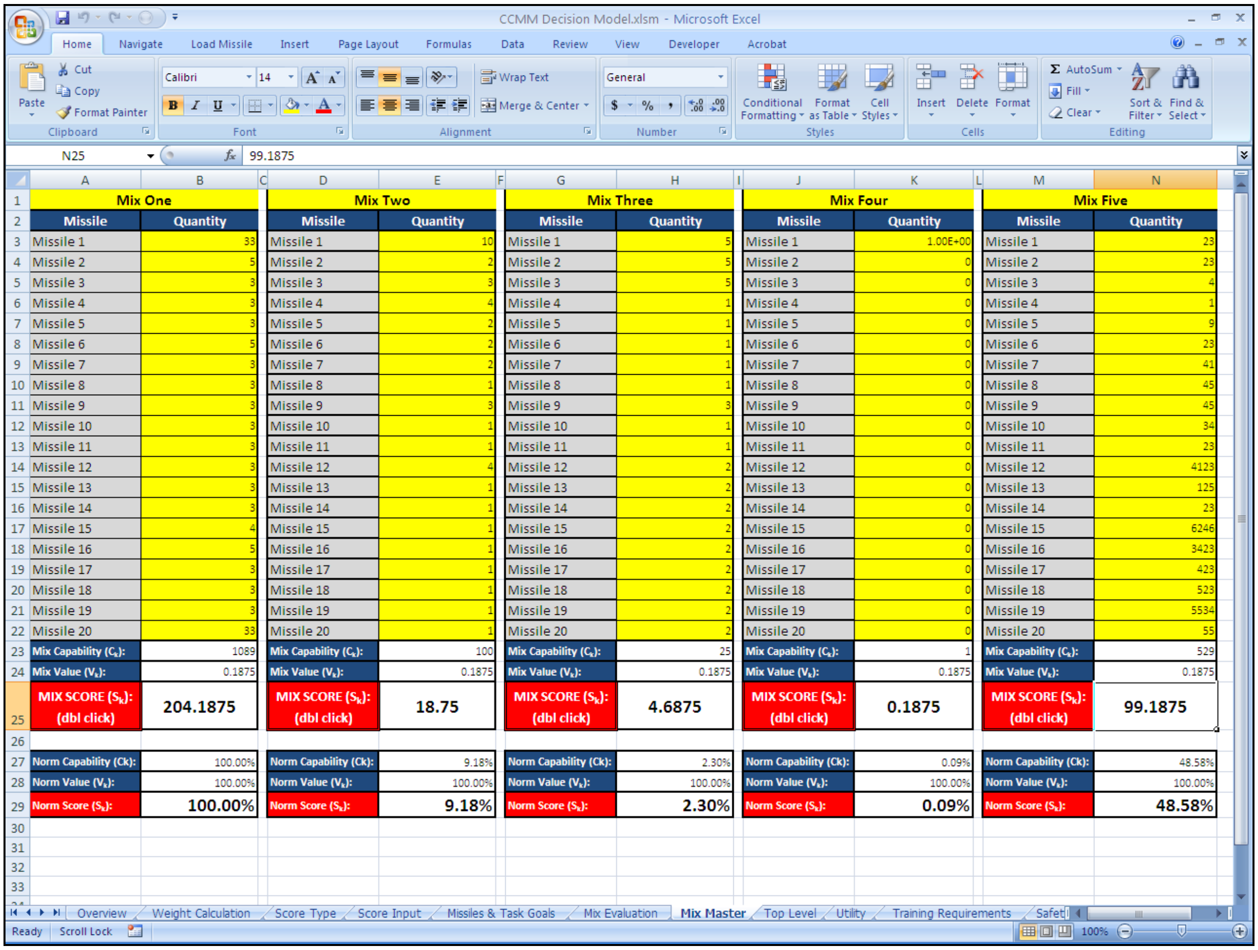
Figure E-28. Invalid Capability Emphasis Value

The “Capability Value (C_k)” and “Mix Value (V_k)” are displayed automatically and the “Total Mix Score (S_k)” is calculated from these two values. The total mix score provides the overall value of the missile mix under consideration and can be compared to the total mix score of other missile mixes to determine the best missile mix against a given set of objectives. Total mix scores can also be calculated on the “Mix Master” worksheet. However, these scores are calculated relative to other mixes meaning the highest scoring mix always receives a total mix score (S_k) of 100. The same is true for the capability values (C_k) and mix values (V_k) that appear in the “Mix Master” worksheet. This calculation is discussed in the next section.

Note: Experimental results using the Excel™ Solver to find the mix that provided the maximum score has shown that this methodology will continue to assign missiles to accomplish low risk (as measured by the product of likelihood and importance) task goals even if that product is quite small. It is therefore recommended that the risk of each task goal be reviewed and that careful consideration be given to dropping task goal whose risk is below five percent (5%).

E.3.8 Mix Master Worksheet

The “Mix Master” worksheet (shown in Figure E-29) allows the user to quickly edit, evaluate, and view a summary of missile mix evaluations to compare them to other missile mixes. The “Mix Master” worksheet can compare up to five missile mixes at one time and limits the user to editing missile quantities to compare missile mixes. If more edits other than missile quantities are required between missile mixes, the mix score must be calculated via inputs to the “Missiles & Task Goals” and “Mix Evaluation” worksheets. For this reason, it is recommended that the “Mix Master” worksheet be used to edit and perform mix evaluations only for comparisons of mixes with the same task goals and missile types.



	A	B	D	E	G	H	J	K	M	N
1	Mix One		Mix Two		Mix Three		Mix Four		Mix Five	
2	Missile	Quantity	Missile	Quantity	Missile	Quantity	Missile	Quantity	Missile	Quantity
3	Missile 1	33	Missile 1	10	Missile 1	5	Missile 1	1.00E+00	Missile 1	23
4	Missile 2	5	Missile 2	2	Missile 2	5	Missile 2	0	Missile 2	23
5	Missile 3	3	Missile 3	3	Missile 3	5	Missile 3	0	Missile 3	4
6	Missile 4	3	Missile 4	4	Missile 4	1	Missile 4	0	Missile 4	1
7	Missile 5	3	Missile 5	2	Missile 5	1	Missile 5	0	Missile 5	9
8	Missile 6	5	Missile 6	2	Missile 6	1	Missile 6	0	Missile 6	23
9	Missile 7	3	Missile 7	2	Missile 7	1	Missile 7	0	Missile 7	41
10	Missile 8	3	Missile 8	1	Missile 8	1	Missile 8	0	Missile 8	45
11	Missile 9	3	Missile 9	3	Missile 9	3	Missile 9	0	Missile 9	45
12	Missile 10	3	Missile 10	1	Missile 10	1	Missile 10	0	Missile 10	34
13	Missile 11	3	Missile 11	1	Missile 11	1	Missile 11	0	Missile 11	23
14	Missile 12	3	Missile 12	4	Missile 12	2	Missile 12	0	Missile 12	4123
15	Missile 13	3	Missile 13	1	Missile 13	2	Missile 13	0	Missile 13	125
16	Missile 14	3	Missile 14	1	Missile 14	2	Missile 14	0	Missile 14	23
17	Missile 15	4	Missile 15	1	Missile 15	2	Missile 15	0	Missile 15	6246
18	Missile 16	5	Missile 16	1	Missile 16	2	Missile 16	0	Missile 16	3423
19	Missile 17	3	Missile 17	1	Missile 17	2	Missile 17	0	Missile 17	423
20	Missile 18	3	Missile 18	1	Missile 18	2	Missile 18	0	Missile 18	523
21	Missile 19	3	Missile 19	1	Missile 19	2	Missile 19	0	Missile 19	5534
22	Missile 20	33	Missile 20	1	Missile 20	2	Missile 20	0	Missile 20	55
23	Mix Capability (C_k):	1089	Mix Capability (C_k):	100	Mix Capability (C_k):	25	Mix Capability (C_k):	1	Mix Capability (C_k):	529
24	Mix Value (V_k):	0.1875	Mix Value (V_k):	0.1875	Mix Value (V_k):	0.1875	Mix Value (V_k):	0.1875	Mix Value (V_k):	0.1875
25	MIX SCORE (S_k): (dbl click)	204.1875	MIX SCORE (S_k): (dbl click)	18.75	MIX SCORE (S_k): (dbl click)	4.6875	MIX SCORE (S_k): (dbl click)	0.1875	MIX SCORE (S_k): (dbl click)	99.1875
26										
27	Norm Capability (Ck):	100.00%	Norm Capability (Ck):	9.18%	Norm Capability (Ck):	2.30%	Norm Capability (Ck):	0.09%	Norm Capability (Ck):	48.58%
28	Norm Value (V_k):	100.00%	Norm Value (V_k):	100.00%	Norm Value (V_k):	100.00%	Norm Value (V_k):	100.00%	Norm Value (V_k):	100.00%
29	Norm Score (S_k):	100.00%	Norm Score (S_k):	9.18%	Norm Score (S_k):	2.30%	Norm Score (S_k):	0.09%	Norm Score (S_k):	48.58%

Figure E-29. The "Mix Master" Worksheet

The "Mix Master" worksheet contains a table for each of the five potential missile mixes under consideration. The mixes can be named by typing the desired name in appropriate cells at the top cell of a table that are highlighted in yellow. The "Missile" column is automatically populated with the missile names from the "Missile & Task Goals" worksheet. The quantities under the "Quantity" column can be edited for each missile. To specify a missile quantity, click inside the "Quantity" column for the appropriate missile and enter a value of at least zero. If a non-numeric value or a numeric value less than zero is entered, a message box (shown in Figure E-30) will appear prompting the user to enter a value of at least zero. Note that while the missile mix will be evaluated based on the missile quantities supplied in the "Quantity" column, only those missiles for which the "Use in Mix?" value is "Yes" on the "Missiles & Task Goals" worksheet will actually have an impact on the mix evaluation calculation. It is recommended to set all "Use in Mix" values for missiles in the "Missiles & Task Goals" worksheet to "Yes" when using the "Master Mix" worksheet.

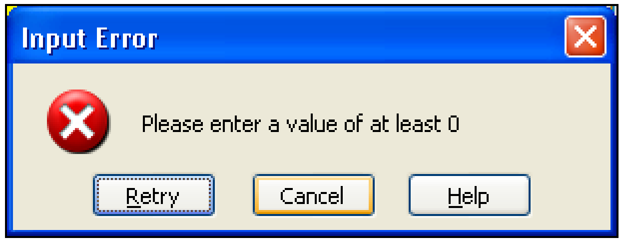


Figure E-30. The Invalid Missile Quantity Message Box

After the desired quantities have been entered for each missile, double-click on the cell labeled “Mix Score: (dbl click)” shown in Figure E-31 to perform the mix evaluation. This causes the missile quantities entered on the “Mix Master” worksheet to be copied into the corresponding quantity cells on the “Missiles & Task Goals” worksheet overwriting any quantity data currently existing in those cells. Then the mix capability, mix value, and mix score are calculated The “Mix Capability (C_k)”, “Mix Value (V_k)”, and “Mix score (S_k)” from the “Mix Evaluation” worksheet are displayed on the “Mix Master” worksheet below the “Mix Score: (dbl click)” cell.

Additionally, the “Norm Capability (C_k)”, “Norm Value (V_k)”, and “Norm score (S_k)” are displayed for each mix. These values are the normalized capability (C_k), value (V_k), and mix scores (S_k) calculated with respect to all current mixes being evaluated. The mix with the highest overall mix score (S_k) is given a value of 100 while all other mix scores are normalized to be from zero to 100% of the highest mix score (S_k). The same is true for the mix capability (C_k) and the mix value (V_k). Therefore, if only one mix is being considered on the “Mix Master” worksheet, it will automatically receive a score of 100 for each of its normalized scores, as it is the best mix under consideration.

Figure E-31 The “Mix Score” Button on the “Mix Master” Worksheet

E.3.9 Detailed CCM-DH (Top Level, et al) Worksheets

In addition to the missile input worksheets and the mix methodology worksheets, the CCMM Decision Model has several worksheets dedicated to each sub-level of the DH. These worksheets allow the user to view in-depth CCM-DH information for any missile that has been evaluated and scored on the “Score Input” worksheet. Each worksheet displays exactly one attribute of the CCM-DH as evaluated for the given missile along with all of the attribute’s sub-attributes. The user can navigate through the CCM-DH via this series of separate worksheets to view an in-depth summary of the scores and weights for each sub-level of the CCM-DH as evaluated for a specified missile. All of the worksheets that display CCM-DH sub-level information are locked so that users cannot edit or delete information. These worksheets serve as a read-only viewing tool rather than as an editing tool.

E.3.9.1 Selecting a Missile to Display Information

First, the user must specify the missile for which the CCM-DH information should be displayed. The default settings load the CCM-DH information for the first missile evaluated in the “Score Input” worksheet, which corresponds to the missile that appears the farthest left in the consecutive columns of scoring in the “Score Input” worksheet.

The user can easily change which missile's data is displayed in the CCM-DH sub-level worksheets by using the "Load Missile" tab located on the Excel ribbon at the top of the screen. The "Load Missile" tab is accessible from any worksheet in the CCMM Decision Model. This tab is shown in Figure E-32. To specify the missile for which the CCM-DH sub-level worksheets display information, click on the desired missile name in the tab. This will load the correct information for that missile and default to the "Top Level" worksheet.

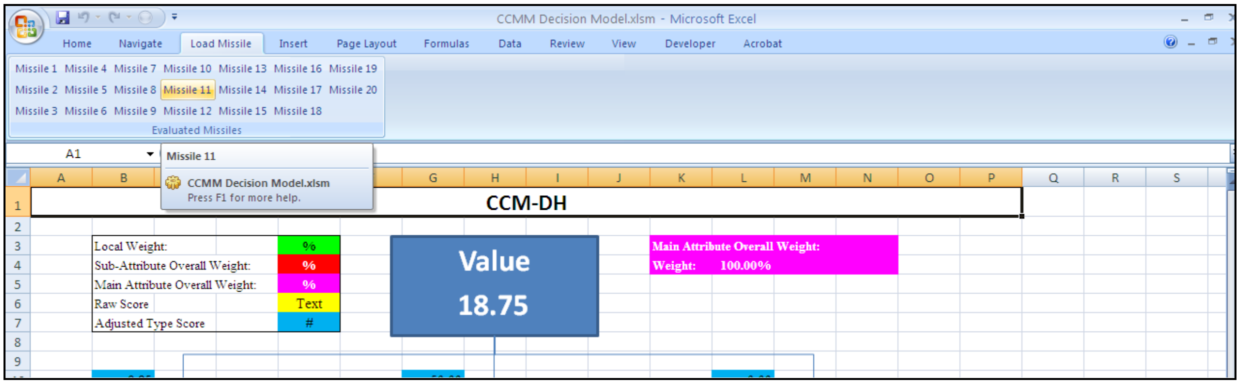


Figure E-32. The "Load Missile" Tab

The missile information may take a few seconds to load and the message box shown in Figure E-33 appears while the missile information is loading.

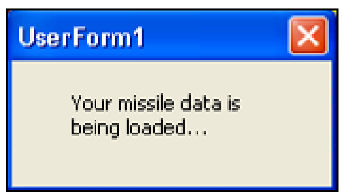


Figure E-33. The "Load Missile" Message Box

The "Top Level" worksheet as shown in Figure E-34 displays the first three sub-attributes "Safety," "Combat Capability," and "Safety" of the highest attribute, "Value" which is the final CCM-DH score for a given missile. Non-leaf attributes are represented by blue boxes while leaf attributes are represented by green boxes. Blue circles are connectors to sub-levels of the CCM-DH. Each worksheet is named after the main attribute that appears at the top of the worksheet.

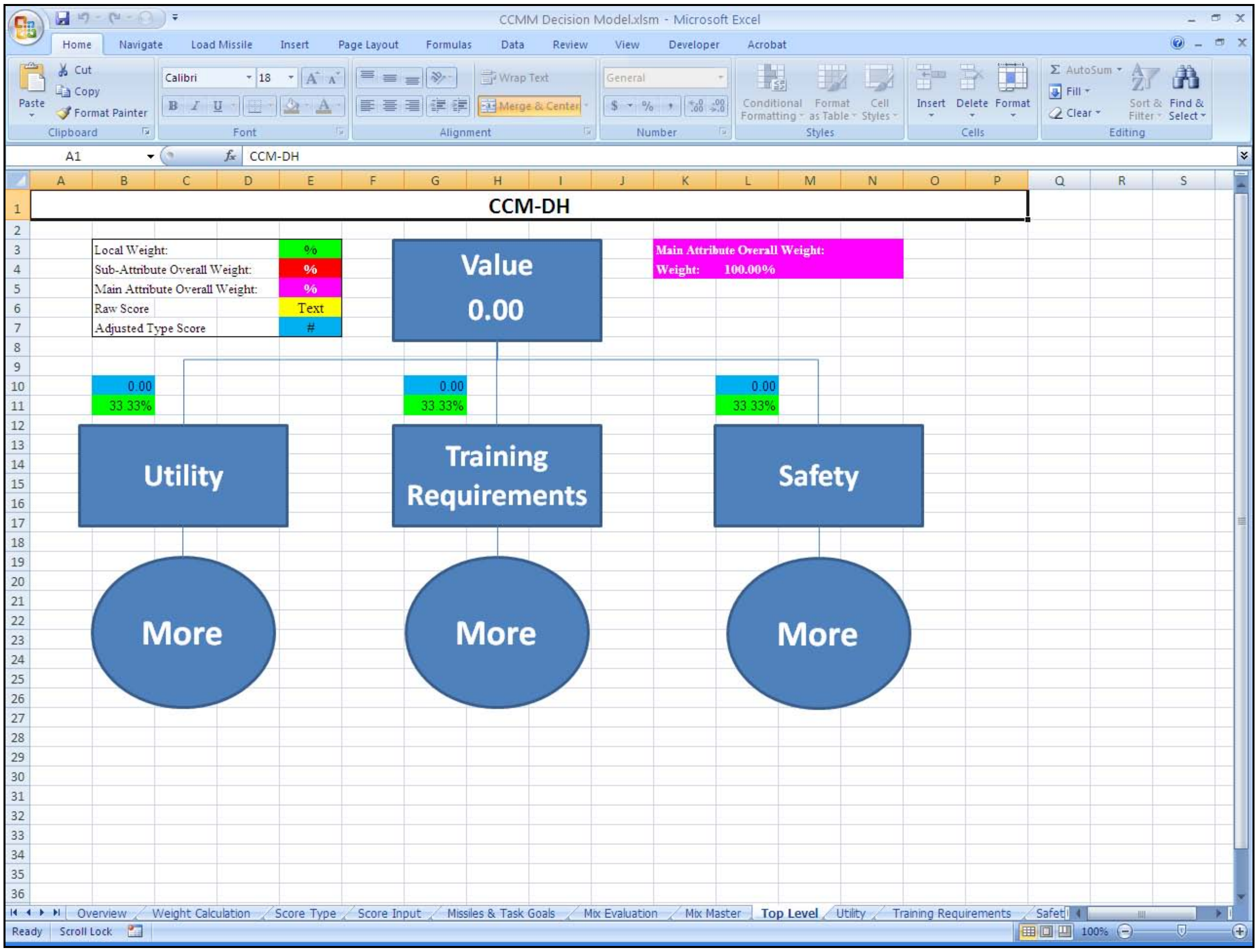


Figure E-34. The "Top Level" Worksheet of the CCMM Decision Model

E.3.9.2 Reading the Worksheet

On each of the CCM-DH sub-level worksheets, the various model inputs are color coded and correspond to user input or model calculation columns from the "Weight Calculation" and "Score Input" worksheets. In the upper right hand of each worksheet, a small color-coded table serves as a key for the color scheme and units used for all values displayed on the worksheet. This key is shown in Figure E-35.

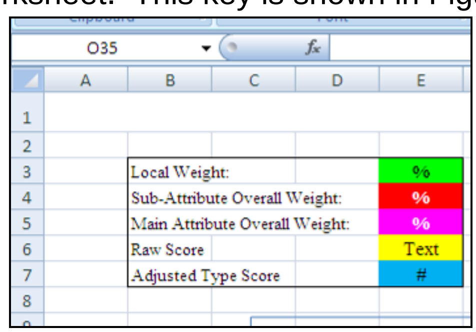


Figure E-35. The Color Scheme Key for the CCM-DH Worksheets

The first row of the table titled "Local Weight" indicates that local weights for each sub-attribute in the worksheet are displayed as percentages with a bright green fill color. Local weight corresponds to the "Local Weight" column from the "Weight Calculation" worksheet and represents the weight of a sub-attribute in relation to its siblings, which

are attributes on the same level of the CCM-DH possessing the same parent attribute. This value is displayed above each sub-attribute in the worksheet.

As indicated by the second row of the table "Sub-Attribute Overall Weight" is displayed as a percentage with a red fill color. "Sub-Attribute Overall Weight" corresponds to the "Overall Weight" column from the "Weight Calculation" worksheet for the sub-attributes and gives the sub-attribute's weight in relation to the final CCM-DH score of the missile. On the "Top Level" worksheet, this value is omitted for each sub-attribute as the local weight is equal to the overall weight because these attributes appear on the first sub-level of the CCM-DH. This value is displayed above each sub-attribute in the worksheet right below the sub-attribute's local weight.

The third row of the table indicates that "Main Attribute Overall Weight" is displayed as a percentage with a pink fill color. "Main Attribute Overall Weight" corresponds to the "Overall Weight" of the attribute from the "Weight Calculation" worksheet and is displayed to the right of the main attribute that appears at the top of the worksheet.

As indicated in the fourth row of the table, "Raw Score" is displayed as text with a yellow fill color. The "Raw Score" corresponds to the "Raw Score" column of the "Score Input" worksheet and only is displayed for leaf attributes. When displayed, this value appears above the sub-attribute.

The fifth row of the table indicates that "Adjusted Type Score" is displayed as a percentage with a blue fill color. The "Adjusted Type Score" corresponds to the "Adjusted Type Score" column of the "Score Input" worksheet and is displayed for all attributes.

E.3.9.3 Navigating Between the Worksheets

There are several ways for the user to navigate to different worksheets to view different sub-levels of the CMM-DH. Once inside any of the CCM-DH sub-level worksheets, click on the purple button (shown in Figure E-36) in the upper right-hand corner below the "Main Attribute Overall Weight" label to return to the worksheet that displays the CCM-DH level above the current level. Each button is labeled with the name of the worksheet to which the button will return the user. To navigate to a lower level of the CCM-DH, click on any blue circle labeled "More." This navigates to the next level of the CCM-DH below the sub-attribute under which the "More" circle was clicked.

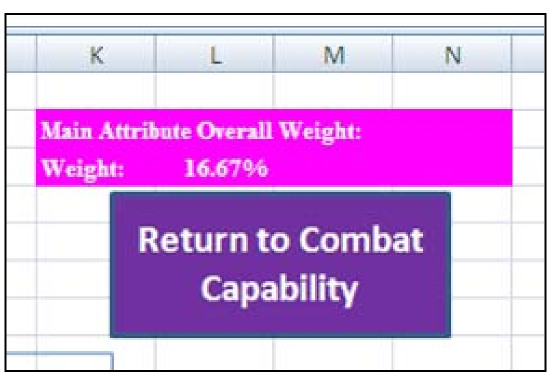


Figure E-36. The "Return to…" Button

An alternative method for navigating through the worksheets is provided in the form of a "Navigate" tab located on the Excel Ribbon at the top of workbook. To view the "Navigate" tab, click on "Navigate" on the Excel Ribbon. The "Navigate" tab is

accessible from any worksheet in the CCM-DH. The list of CCM-DH sub-level worksheets to which the user can navigate is initially limited to the sub-attributes of the “Top Level” worksheet to prevent the user from having to scroll through large numbers of groups to find the desired worksheet (as shown in Figure E-37). To navigate to a different worksheet, click on the name of the worksheet desired for viewing in the “Navigate” tab. New groups of worksheet names appear when worksheet names are clicked. These worksheets represent sub-levels of the CCM-DH that branch out from the selected worksheet’s main attribute.

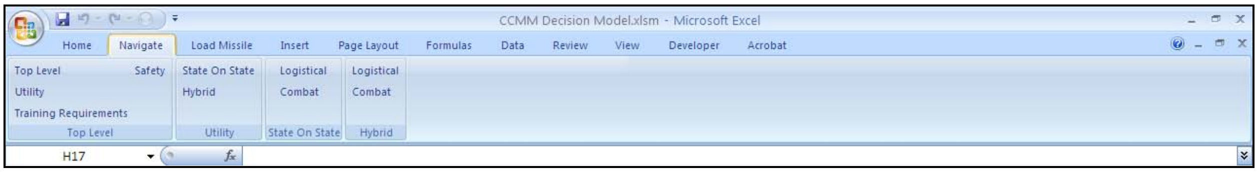


Figure E-37. The “Navigate” Tab

Additional categories are visible in the “Navigate” tab in Figure E-38. These worksheets are worksheets containing CCM-DH sub-levels “State-on-State” worksheet. Clicking on one of these worksheet names takes the user directly to the corresponding worksheet. The “Navigate” tab allows the user to select any CCM-DH sub-level worksheet in as little as two clicks.

Figure E-38. The “Navigate” Tab for “State-on-State”

Appendix F TBS Instructor Interviews

Subject: Meeting Notes— Close Combat Missile Model Study, TBS Working Meeting

Date: 17 June 2010

Place: The Basic School (TBS), Gonzales Hall

Time: 0900-1000

Attendees:

Mr. Steve Stevens OAD, MCCDC

Pvt Palmer TBS (0351/0352)

Cpl Burnett TBS (0351)

Sgt Morelli TBS (0351)

Sgt Fultz TBS (0351?)

Mr. Edd Bitinas Northrop Grumman Study Team

Mr. Andrew Hucke Northrop Grumman Study Team

Mr. Mike Meiners Northrop Grumman Study Team

Discussion:

Mr. Bitinas provided a brief overview of meeting goals, emphasizing the focus on understanding close combat missile (CCM) use in hybrid warfare.

Sgt Fultz stated that he used the TOW system in Fallujah. He did not fire the missile much but very often used the TOW thermal site, for example, looking for insurgents placing improvised explosive devices (IED). If persons were observed placing an IED, they would usually engage them with a M240 or .50 caliber machine gun instead of a TOW missile. In Ramadi, the large numbers of IEDs and sniper made it unsafe to deploy the TOW on the HMMWV platform due to the lack of armor protection for the TOW gunner.

Cpl Burnett stated that he used the SMAW frequently in Fallujah. In Fallujah they were not concerned much with excessively damaging buildings. The dual mode rocket causes less collateral damage. The novel explosive (NE) rocket can cause a lot of collateral damage. He fired an NE round into a 3000 sq. ft. chicken factory causing the building to collapse. He had used the dual mode rocket to destroy small parts of buildings. He fired a TOW missile at a building and it penetrated the front of the building and blew a large hole out of the rear. In one instance a dual mode rocket was used to engage a passenger car, the round passed through the door, into the car, and out through the opposite door without detonating. The TOW missile, when used for anti-structure operations, provides more penetration than the SMAW NE, but less explosive damage. The SMAW NE is almost sure to destroy the building, or large parts of it.

Sgt Morelli recounted an event in Ramadi when a tank was used to engage a sniper in a building. The tank fired into the building causing the sniper to stop firing, however, the sniper resumed firing after about 20 minutes. The tank fired another round into the building again causing the sniper to stop firing. As before the sniper resumed firing after

a short time. A SMAW NE was then fired into the building at the floor below the sniper location, destroying a large part of the building and killing the sniper. The NE does cause a lot of collateral damage but it does “take care of the problem.”

Sgt Morelli added that there is a misconception in the Marines that the SMAW high explosive dual purpose (HEDP) rocket is a good breaching tool. It typically only creates a basketball sized hole in a wall.

Sgt Fultz concurred on the lack of breaching effectiveness of the HEDP. He added that the NE rocket is great when collateral damage is not a concern.

Cpl Burnett stated that a good team could have success breaching a building [with HEDP]. Tactics such as firing at the space under a window, the frame of a door, or the corner of a structure can be effective, however success requires a very experienced team.

Sgt Morelli agreed stating that the misconception that [HEDP] is a good general breaching tool, while in reality breaching requires a very experienced team. Firing at a blank wall was ineffective.

Cpl Burnett stated that the stated range of the SMAW is under its capability. He has seen the SMAW fired 700m into a building to take out a machine gun. The rocket tracer only works out to 500m, a good improvement would be to extend the tracer range.

Sgt Fultz stated that the TOW Saber was able to score a hit on a tank from 3800 meters fired from a HMMWV. He suggested that a good improvement for the HMMWV TOW would be improving the armor protection for the gunner.

Pvt Palmer stated that his MOS is 0351/0352 and that he had fired the Javelin missile in combat. While in Fallujah, their TTP was to engage any vehicle that did not have its doors and trunk/hood open. The Javelin was used to engage a flat bed truck. The Javelin was chosen because they were in a narrow street with power lines. Pvt Palmer had to get authorization from the Bn commander before firing at the truck with the Javelin. Pvt Palmer stated that the requirement for high-level approval before use is a bad characteristic of the Javelin missile. When the missile was fired, it destroyed the cab of the truck. It is his opinion that the Javelin is a better missile than the TOW missile [assuming TOW anti-armor] but that the TOW Saber has better optics. Its main charge is equivalent to Naval gun fire. The Javelin Command Launch Unit (CLU) is still a very good optic that can be used during day and night. He said the CLU was great for observation and allowed Marines to pick out enemy snipers from a bunch of pigs, which a thermal sight would’ve been unable to accomplish.

Pvt Palmer stated his unit had used a Javelin and a TOW to engage two trucks inside a firehouse-like building. The Javelin was fired first, then the TOW. The TOW is a good breaching tool. Even though the TOW anti-armor round is not intended for breaching they can get it to work effectively. He stated that all missiles would do some type of damage to a structure and typically suppress return fire for a period.

Sgt Fultz stated that he had used an AT-4 to engage a flat bed truck next to which an insurgent was laying an IED. The missile destroyed the truck and the insurgent. He added that CCMs are a good tool to use to make the enemy stop shooting at you.

Pvt Palmer stated that the new LAW, used by 0311, is a pretty good breaching tool, it can break down metal doors. The new LAW can be closed [for later use] after it has been extended, the old version, once extended, could not be closed and had to be fired.

Pvt Palmer stated that his main issue with the Javelin was that the argon cooling gas for the missile only lasts four minutes, if the missile is not fired within that time it is no longer usable.

Cpl Burnett stated that he had experienced three misfires in a row using a SMAW. He mentioned that the spotting tube had broken. The SMAW has some breakable components and in general, the SMAW should be made sturdier. I think he also said something about a tube exploding.

Cpl Burnett stated that while the SMAW back blast area is large it is probably not as large as documented.

Pvt Palmer stated that the TOW also has back blast concerns. The back blast hinders adding armor to a TOW platform.

Sgt Fultz added that he would like to have an M240 in the [TOW] turret.

Pvt Palmer stated that the USMC is the only US force that uses the SMAW, which hinders its improvement. The lack of funding is hindering the implementation of fixes. The USMC is just piling more gear onto a Marine rather than improving weapon systems. Portability of systems is affected by the amount of gear a Marine is being asked to wear. He noted a study where Lockheed Martin loaded up Marines and observed and took data on their mobility.

Sgt Fultz stated that there are space limitations with the HMMWV and the Saber system. Need to carry “beans, bullets, and band aids” and room is a big issue that needs to be considered.

Sgt Morelli stated that at the SMAW working group, the [party responsible for selecting improvements/changes to be made] would not give enough credence to the opinions and ideas proposed by the actual enlisted Marine operators of the system.

Pvt Palmer agreed that [weapon] contractors need to listen to the users and that the SMAW II is a step in the right direction.

Cpl Burnett stated that he would like the telescopic site removed from the SMAW. The site offers a bad field of view. He would rather not be responsible for it [it is fragile as previously mentioned]. The SMAW needs an Advanced Combat Optical Gunsight (ACOG) that will hold BZO.

Pvt Palmer stated that squad automatic weapon (SAW) does not need a scope.

Pvt Palmer commented that the USMC spends $1.2 Million on Marine Day shooting stuff for congressional staffers to watch.

Cpl Barnett suggested that the Study Team continue to talk to NCOs vs. officers regarding CCMs as the users are the SMEs.

Subject: Meeting Minutes - Close Combat Missile Methodology (CCMM) Study Ft. Benning, GA Site Visit

Date: 28 June 2010

Place: Close Combat Missile Cell (CCMC), Maneuver Center of Excellence (MCE), Ft. Benning, GA.

Time: 1430 - 1800

Attendees:

Mr. Donald Murray, Current Operations, CCMC, MCE, Ft. Benning, GA.

Mr. Terry Hemminger, TOW Missiles CCMC, MCE, Ft. Benning, GA.

Mr. George Gurrola, Javelin Weapon System CCMC, MCE, Ft. Benning, GA.

Mr. Iric Bressler, Marine Corps Combat Development Command (MCCDC), Operations Analysis Division (OAD)

Mr. Edd Bitinas, Northrop Grumman

Mr. Andrew Hucke, Northrop Grumman

Discussion:

The meeting began at approximately 1430 hours at the U.S. Army Close Combat Missile Cell, Maneuver Center of Excellence, Ft. Benning, GA.

The Army briefings discussed in these meeting minutes have been forwarded to the Government Study Lead via separate emails because of the file size. The Study Team briefings discussed are embedded at the end of these meeting minutes.

After introductions, Mr. Bressler provided a short introduction as to why the Marine Corps Study Team was talking to the Army about Close Combat Missiles (CCM); specifically the study was being conducted to assist decision makers in deliberations regarding what types of missiles to procure to replenish current inventories.

Mr. Hemminger stated that about 1000 Javelins and 9000 TOW missiles have been fired by Marine Corps (USMC) and Army personnel during combat operations in Iraq and Afghanistan. He mentioned that soldiers were often told not to engage with missiles in favor of engaging with artillery or aircraft. Mr. Hemminger said some units would fire more missiles than other units would and gave an example of the 173rd Airborne Brigade Combat Team (ABCT) having shot over 100 missiles during their recent tour.

Mr. Murray said the Army is pretty far along with new capabilities and would begin to improve the TOW in a few years as well.

Mr. Bitinas discussed the reason the Study Team was visiting Ft. Benning. He briefly outlined the first few slides in the Close Combat Missile Methodology Study Topics for Discussion briefing (attached to these meeting minutes). He discussed the study background in slide 1, and the objective and approach in slide 2. Mr. Bitinas said that anti-armor information is sufficient but there was very little information available on firing missiles at structures/buildings. He stated munitions requirements seemed to be determined in Cold War fashion and no combat models deal with shooting at

structures/buildings. Mr. Bitinas also stated the ammunition requirements for anti-structure/building missile use are unclear. He said the Study Team had decided to use an Analytic Hierarchy Process (AHP) model and the USMC could populate the model with data after it was completed. Mr. Bitinas briefly explained how an AHP model worked.

Mr. Bitinas discussed the objectives of the Site Visit to Ft. Benning in slide 3. He also explained the problems the Study Team was attempting to solve: 'What should the close combat missile weapons mix look like?' and 'How will the close combat missile effectiveness be scored?'

Mr. Murray mentioned that post-combat surveys are given to Army units. Mr. Bitinas asked if those surveys are stored in a system. Mr. Murray responded that the survey data was sent to Ft. Leavenworth.

Mr. Murray asked when the CCMM Study would be completed. Mr. Bitinas responded that the study was scheduled to be completed in October 2010. Mr. Murray suggested that we use the survey data for the study. Mr. Gurrola said the 4th Brigade Combat Team (BCT), 4th Infantry Division (ID) is returning to Ft. Carson, CO from deployment and will be surveyed about the use of CCMs. Mr. Murray mentioned there will be several additional opportunities and he would try to coordinate with the Marine Corps.

Mr. Murray mentioned the Shoulder Launched Munitions (SLM) department is working on a munition that can defeat light armor and breach the walls of structures/buildings.

A video of the assault on Marjah, Afghanistan, where CCMs were utilized, was shown.

Mr. Murray said the point of the Javelin was to engage/destroy a threat without having to call in an airstrike. He then presented the Extended Range Line-of-Sight (ERLOS) Lethality briefing. It identifies capability gaps for the Brigade Combat Teams. He said this briefing covered the missiles available for early entry and expeditionary forces (no artillery, air support, etc.). The Firepower Branch looked at what the correct missile mix would be. Based on fiscal constraints, the solution would probably be TOWs or Javelins. The briefing was the second version and it was likely to be approved. The Army focuses on range and lethality when evaluating CCMs. Some of the hardest targets that are engaged with CCMs are triple brick walls and houses; this type of structure is very prevalent in Iraq and Afghanistan.

Mr. Bitinas mentioned that a few recently interviewed USMC NCOs said that a Javelin could only be fired if their battalion commander approved it. Mr. Murray said that this was a known issue in the Army and mentioned that often targets in Iraq would slip away before the authorization was obtained. Obtaining authorization reportedly has not been as much of an issue in Afghanistan. Mr. Hemminger said the 425th Brigade Special Troops Battalion (BSTB), having recently returned from their tour, was not able to use the Javelin due to excessive authorization requirements.

Mr. Murray mentioned that regardless of the changes and modifications to CCMs, these weapons would always have an anti-armor capability. Mr. Bressler asked if the Raven UAV was being used by Army squads. Mr. Murray said the Army wanted the squads to have the Raven but it could potentially clutter the airspace.

Mr. Murray said there was a man portable UAV under development that could carry a warhead and an individual soldier could fly it into a target. However, the target must be within a 10 minute flight. It was also mentioned that Stryker Brigades had 121 Javelins and 9 TOWs and the Army was working on tactics, techniques, and procedures (TTPs) for man portable UAVs in theater.

Mr. Murray presented the Close Combat Missile Capability Gaps briefing. It identifies capability gaps and science and technology initiatives to close those gaps. He said these gaps all pertained to the inability to see, shoot, or kill targets at range.

Mr. Murray said 7100 meters (4.4 miles) was the limit of detection range. He mentioned the Improved Target Acquisition System (ITAS) could see far but was not man-portable.

Mr. Murray said that “administratively,” the Army doesn’t shoot at people with missiles, but in reality, they do. Mr. Bressler said that MARCORSYSCOM has a mindset against shooting missiles at people. Mr. Murray said that relying on mortars to engage insurgents laying IEDs was much slower than engaging them with a missile.

Mr. Bressler asked how the capability gaps were ordered from hardest to easiest to fill. Mr. Murray said kinetic energy missile technology would eventually happen but it is currently too expensive. Incremental improvements were the best way to handle missile system improvements.

Mr. Bressler asked if any Urgent Need Statements (UNS) have come through about CCMs. Mr. Murray said units often didn’t know what to ask for because they didn’t know what was available. He mentioned that multipurpose warheads for Javelins came from this process. The multipurpose warheads would be employed around the 2012 or 2013 timeframe. Soldiers in the field didn’t know these warheads were being produced.

Mr. Murray next showed the Army Missile Capability Gap Assessment briefing.

The briefing provides a prioritized assessment of the materiel capability gaps. He said that initially the Army Capabilities Integration Center (ARCIC) said air and artillery could deal with all threats. The Firepower Division had ARCIC conduct a new study considering CCMs as well. The new document was signed off and the Firepower Division was instructed to improve the Javelin. The Army Missile Capability Gap was the guiding document for this action.

Mr. Murray mentioned that text in the briefings was red if it was believed to be useful to what the Study Team was doing with CCMs. The shoulder-launched munitions were the AT-4, the Shoulder-launched Multipurpose Assault Weapon (SMAW)-D, and the M72 LAW.

Mr. Bressler asked how many of the 10,000 Hellfire missiles that were fired were replenished. No one was sure of the answer. Mr. Gurrola stated that the Marine Corps was going to buy some bunker busters was an assumption, and that he would get the actual number of Hellfire missiles replenished.

Mr. Hemminger said 500 TOW-2 Bunker Busters (BB) were sent over for Stryker Brigade Combat Teams (SBCTs) that initially had to be fired under armor; 1,200 to1,300 TOW-2BBs had been sent over that could be fired while dismounted. He didn’t know if TOW-2A and TOW-2B were being replenished.

Mr. Murray said he didn't know where the ammunition requirements numbers originated. The manufacturer's business requirements, namely the ability to keep production lines open, play a part in buying the ammunition. Mr. Hemminger said new missiles will replace TOW-2A and TOW-2B, but the new capability wasn't needed for the current fight in Iraq and Afghanistan.

Mr. Murray said systems #4, Non-Line of Sight (NLOS) and #5, Guided Multiple Launch Rocket System (GMLRS Unitary) as shown in the slides, were essentially "dead" systems. Mr. Bressler asked for a description of the concept of the Individual Assault Munition (IAM). Mr. Murray said it was supposed to breach triple brick and some adobe structures. The Army leadership drove the requirement for IAM weight down to 12 pounds and it became too close to the M72 (LAW). The goal is to fit the IAM into an M72 package.

Mr. Murray showed some ground capability gaps. The applicable gaps were in shown in red. The Firepower Division was told to look at networking their systems. Mr. Hemminger asked what would happen with system #11 (IAM) which had disappeared. Mr. Murray said the technologies that were gone would be transitioned.

Mr. Murray said Raytheon's Griffin 12-14 mile missile was being looked at for NLOS applications. He noted that the Precision Guided Munition (PGM) for the 120mm mortar goes about as far as ground systems need to go. It had to be fired at a stationary target.

Mr. Murray asked about non-lethal weapons. Mr. Bressler said there was not much focus on non-lethal weapons as far as the study was concerned. Mr. Murray said he had been asked about developing non-lethal missiles before. Mr. Bressler said non-lethal weapons in the USMC were at the squad and platoon level and were mostly used for crowd control situations.

Mr. Murray presented the Close Combat Missile Systems briefing. The briefing outlined some residual gaps in CCMs and provides science and technology research initiatives that will attempt to close those gaps.

Mr. Murray said the gap is a yearly local study to identify gaps and determine if capabilities were available to mitigate those gaps. Networking was a big piece of the gap analysis. No one in the Army was sure what the network might look like. Mr. Bressler said there was no capability to get ISR aircraft photos to a battalion commander. Mr. Murray said the Army was working on doing that. Mr. Bressler said the USMC could do it because it is something they focus on. He said that's how the USMC thinks of networking. Mr. Murray said networking may be forced out because no one knows what it should look like.

Mr. Murray said there was an issue with photos becoming classified and not being able to be passed down. He also stated Government systems are too restrictive, which hampers dissemination of information.

Mr. Murray explained that a multi-target warhead could hit multiple types of targets, not multiple targets with one shot. Joint Capability Integration and Development (JCID) came down to two documents: one used for the Javelin and one used for the TOW. He said that USMC input would be useful for gap 6, which addressed multi-mode fuses and warheads.

Mr. Murray said the Army was trying to increase sight range and add an abort function to missiles. He said in the future that the Army wanted a warhead that can destroy armor and penetrate triple brick structures.

Mr. Murray said Aviation and Missile Research, Development and Engineering Center (AMRDEC) in Huntsville, AL figured out the multipurpose sleeve for the Javelin. There are several Research, Development, and Engineering Centers (ARDECs) that work on different things. He added that missile component modernization was a big field of research; many of the missile components are 1980s technology.

Mr. Murray mentioned that network lethality led to a lot of heated discussions. He showed a slide on warhead lethality. The future warhead would be able to sense what target it is hitting and optimize.

Mr. Murray showed the Close Combat Missile System WSR Update briefing, which provided information on how Javelin and TOW are being used in combat and where each of the two programs was going in the near term.

Mr. Murray said Javelin was #4 and TOW was #5 in priority and they are in the top half or third of systems with recommendations for Research, Development, Test & Evaluation (RDT&E) funding.

Mr. Bressler asked about company operations and if the Army was looking at something similar. He said the Marines were looking at reorganizing platoons to make them more lethal. Companies would have a mixture of capabilities from other companies. Mr. Murray said companies were decentralized. Army company commanders are doing what battalion commanders did 20 years ago. Mr. Bressler said new company organization would require missile mixes to be reassessed. Mr. Murray said the Army decentralized but there was no plus up on weapons.

Mr. Murray said that funding had already been promised for Javelin and TOW. Mr. Bressler asked if every year the fundraising had to be defended. Mr. Murray said that was the case. Mr. Murray said network lethality has dropped a little bit because the Army doesn't yet know what the network is supposed to look like.

Mr. Murray said the 173^{rd} ABCT figured out what the TOW could do and anyone that got within 4 kilometers of them was neutralized. They were being hit by mortar fire, tracked the insurgents firing the mortar, and fired a TOW at them. The threat was out of range of .50 caliber fire and an airstrike would have taken too long.

Mr. Murray mentioned Extended Range Line-of-Sight Lethality Initial Capabilities Document (ICD) was undergoing final review.

Mr. Murray presented the Javelin Weapon System and Modernization Plan briefing, which identified the modernizations plans and timeline for the Javelin.

Mr. Murray said the Block 1 Command Launch Unit (CLU) is being fielded. He said the Block 1 missile was backward compatible with the CLUs. The capabilities of Block 0 and Block 1 CLUs were outlined.

Mr. Murray said Raytheon is working on the next version of the CLU with an Infra Red (IR) camera that can see out to 4 km. The Army was also looking at Generation 3 forward looking infrared (FLIR). One pixel is enough to engage a target with the

Javelin. The Block 1 missile had a little better range; out ranging the maximum sight range.

Mr. Murray asked if the Marine Javelin gunners were trained in the unit or at school. Mr. Bressler said they trained at school but there is also a Javelin week to train new Marines. A Javelin gunner would go to the school once a year to receive refresher training.

Mr. Bressler said After Action Reports (AARs) from Iraq said there weren't enough missiles to shoot at targets. Mr. Murray said during the 2004 timeframe, the Army couldn't get enough missiles into theater.

Mr. Bressler asked how the Army grew Javelin gunners. He asked what happened when they got to E6 and above. Mr. Gurrola said the Javelin was a secondary skill. Mr. Murray said soldiers would be a Javelin gunner for about two years.

Mr. Hemminger asked if privates used to be trained in the Javelin right after basic training. Mr. Gurrola said they would be diversified across the formation. He said that once a soldier became a sergeant he would probably not shoot the Javelin anymore. Mr. Murray said skill identifiers required 80 hours of training.

Mr. Gurrola asked if the USMC had the Javelin in infantry companies. Mr. Bressler said that they were in Weapons Company along with the TOWs.

Mr. Murray showed a slide with capabilities required for multipurpose warheads. He said Multi-Purpose Warhead (MPWH), precision guidance, and a guidance electronics unit (GEU) are all directions the Army is headed. Precision terminal guidance will help a Javelin gunner redirect his aim point. The gunner can move the aim point during the missile flight and kill the missile, if necessary, before it hits the target to avoid collateral damage.

Mr. Murray said the Firepower Branch envisioned that in the future one person could use a CLU while another shoots. He said that the seeker has to be behind the missile. Mr. Gurrola said the two person concept is possible; however, it is difficult to do it within the weight restriction of the missile.

Mr. Gurrola said the last correction had to be made at about 1,200 meters prior to impact. Mr. Murray said an untrained gunner would have trouble doing that.

Mr. Murray said Block 1 MPWH wasn't powerful enough to breach a wall.

Mr. Bressler asked how key performance parameters (KPPs) for the missiles are created. Mr. Murray said they think up requirements then discuss the requirements with engineers and see if their ideas are technically feasible.

Mr. Murray said if the USMC wants to have input, they can tell the Firepower Branch. Mr. Bressler said the Marines like the systems the Firepower Branch develops.

Mr. Bressler said the Study Team is trying to add analysis into the process of determining what missiles to buy. Mr. Hemminger said the Standards in Training Commission (STRAC) said a certain amount of TOW missiles had to be fired per year. He said they eventually specified 1,500 missiles per year but it wasn't funded so it was pulled. Mr. Bressler said the process hasn't failed but it can be improved.

The meeting ended at approximately 1800 hours.

Subject: Meeting Minutes - Close Combat Missile Methodology (CCMM) Study Ft. Benning, GA Site Visit

Date: 29 June 2010

Place: Close Combat Missile Cell (CCMC), Maneuver Center of Excellence (MCE), Ft. Benning, GA.

Time: 0900 - 1130

Attendees:

Mr. Warren Turner, Bunker Defeat Munition Program Office, MCE, Ft. Benning, GA.

Mr. Donald Murray, Current Operations, CCMC, MCE, Ft. Benning, GA.

Mr. George Gurrola, Javelin Weapon System CCMC, MCE, Ft. Benning, GA.

Mr. Terry Hemminger, TOW Missiles CCMC, MCE, Ft. Benning, GA.

Mr. Iric Bressler, MCCDC/OAD

Mr. Edd Bitinas, Northrop Grumman

Mr. Andrew Hucke, Northrop Grumman

Discussion:

The meeting began at 0900 hours.

Mr. Turner gave the presentation: Maintaining Battlefield Primacy, which concentrated on the future of Shoulder-Launched Munitions (SLM) and recommended capturing lessons learned in the schoolhouse.

Mr. Turner said the Army has said that the soldier load needs to be reduced but questioned their seriousness. Every time weight was reduced, more gear was added to make up for the reduction in weight.

Mr. Turner said that in the world of SLMs, an augmented weapon is a lighter weapon. SLMs can kill armored targets in one shot but cannot destroy most structures. Soldiers today don't know what targets they are going to face in the field. He mentioned the probability of hit for SLMs was .5. This meant that if a target required two hits to kill, three missiles would have to be fired to reliably kill the target. A missile with a .9 probability of hit that could defeat triple brick is needed.

Mr. Turner has heard from soldiers that carrying more weight was ok as long as they can defeat the target in front of them. Soldiers also frequently used SLMs for suppressive fire.

Mr. Turner said the soldier needed SLMs that could be fired against personnel as well as be strong enough to defeat hard targets.

Mr. Turner said the Army has 100,000 AT4s but they were all bought within 5 years of each other; resulting in all the AT4s reaching the end of their shelf life over a short period of time.

Mr. Turner mentioned that no soldier is willing to use an old system once a new one has been distributed. The inventory of M72A3 LAWs was down to 3,000. The M72A7 LAW was in the process of being made a program of record and the M72A9 LAW is a

planned follow on. The A7 has an armor penetrating warhead; the A9 is anti-structure. He also mentioned even numbered LAWs (A2, A4, etc.) are capable of firing from an enclosure. The AT4 has a shape charge warhead and the AT4A1 could be fired from an enclosure.

Mr. Turner stated that the AT4 was primarily anti-armor but the Bunker Defeat Munition (BDM) (known as SMAW in the Marine Corps) was primarily anti-structure. He also mentioned the AT4 was 17.9 pounds and the BDM was only 16 pounds.

Mr. Turner said he was asked why the Individual Assault Munition (IAM) is important if it was only one pound lighter. It could defeat both armor and structures and the current SLMs could not.

Mr. Turner said there were more requests for M72s and making it a program of record would make it easier to supply. There are currently no realistic trainers for AT4s, M72s, and BDMs. Mr. Turner stated that even if he had all the training gear it would still take over a year to distribute. Mr. Bressler asked where the Army meant to train. He also said he was shocked the Army didn't know about BDMs. Mr. Turner said there was no real ability to train.

Mr. Bitinas said the Marine NCOs interviewed for the study said the skill of the gunner shooting a weapon made a big difference. Mr. Turner said it was correct that soldiers are not getting the training but that they are also training themselves by communicating with each other. That communication isn't documented so he can't create a training course with it. Often there was not enough time to train deploying soldiers on SLMs and that the SLM's sight should look similar to a rifle sight.

Mr. Turner said that AT4CS and BDM should be taught in the schoolhouse. Soldiers aren't being told what the SLMs should be shot at and what they are used for. He thought some training issues might be fixed this year. The 9mm trainer isn't good enough because the real weapon is very loud with a terrific back blast. He said the first real shot would hit the target but the second shot would miss and the third shot might miss. (The implication is that the soldier firing for the first time would not know what to expect from the shot and would aim well, while the anticipation of the blast of the second shot would make the soldier flinch.) The Army is working on making a blast overpressure environment for training. This would increase the probability of hit. A confident soldier would almost have a 100% chance to hit.

Mr. Bressler asked about the soldier load and why the uniform wasn't included. He said the USMC has been focusing on decreasing the Marine load. The USMC was looking at unmanned systems to help lighten Marine loads.

Mr. Turner said every time the weight of the soldier's load gets decreased more stuff gets added and the load needs to be lightened again.

Mr. Turner said that a common SLM would be very useful to reduce costs such as a LAW or LAW-like munition.

Mr. Hucke asked if metal objects such as cars in the path of a TOW missile could trick the targeting system into attacking the wrong target. Mr. Murray said TOW-2A line of sight won't be distracted by metal objects in their path but TOW-2B on top attack mode can be.

A number of videos from Dugway Proving Grounds (Utah) were shown in which various CCMs were fired at sniper positions and at caves. Mr. Gurrola said troops would shoot at rocks with the missiles to create fragmentation to take out personnel but the multipurpose warhead would be able to create fragmentation on its own. He said Dugway Proving Grounds is the area with conditions that are closest to Afghanistan. The targets in the videos were wearing hand-warmers to allow them to appear in the thermal sights.

After the videos were completed, Mr. Bitinas started briefing the Close Combat Missile Methodology Study Topics for Discussion briefing. He quickly summarized slides 1 through 3.

Mr. Bitinas went over the interview topics for discussion in slide 4. He said MARCORSYSCOM didn't have TTPs for using CCMs in combat against structures.

Mr. Bitinas showed the model characteristics for CCMs in slide 5. He asked if we had forgotten any important characteristics. Mr. Murray mentioned collateral damage goes way down when using a TOW or Javelin. He also mentioned a TOW or Javelin has never been lost to the enemy. Mr. Bitinas said the study team didn't want to commit an error of omission so it was included.

Mr. Bitinas mentioned adding flight path restrictions to the list. He said water and power lines were an issue. Mr. Murray said there haven't been many complaints about water or power lines in Iraq. He mentioned there were issues with the Javelin traveling to an altitude and the commander not accounting for it.

Mr. Bitinas mentioned Rules of Engagement (RoE) restrictions as another characteristic. Mr. Gurrola said RoE restrictions were largely leader based. He said some commanders will want everything called up the chain of command.

Mr. Bitinas showed the CCMs the USMC uses in slide 8. Mr. Gurrola asked what the SMAW-II was. Mr. Bressler said the SMAW-II was the next generation of SMAW and may be similar to the E-SMAW. Mr. Murray mentioned he was in Mesa, AZ and saw the E-SMAW. He said the sight was similar to a Javelin sight.

Mr. Bitinas showed the AHP and Simple Multi-Attribute Rating Technique (SMART) methodology in slide 9. He discussed other tasks the study team has used the AHP for, like the LAV Mortar study, and described the methodology for getting scores from SMEs to populate the AHP model. The characteristics for the AHP model were checked using sensitivity analysis, and showed the scoring system in slide 10.

Mr. Bitinas mentioned some challenges exist in comparing mixes of weapons; for example, there might be missiles in a mix that could be shot 3000 meters and others that could be shot at night, but no single missile could shoot 3000 meters at night.

Mr. Bitinas showed the full AHP hierarchy and walked the group through the hierarchy tree. Mr. Murray mentioned the Army has some data on safety issues and negligent discharge.

Mr. Murray mentioned that none of the current missile systems is designated. Mr. Bitinas mentioned designated could possibly refer to a future vehicle mounted Hellfire.

Mr. Bitinas explained why probability of success was not probability of kill that mission objectives could capture the combined capabilities of the mix.

Mr. Bressler suggested the Firepower Division let us know if they find something that should be added to the AHP hierarchy. Mr. Murray said he would bring the AHP to the Firepower Division's operations research analysts (ORSAs) for their comments.

Mr. Bressler said the Study Team needed to finalize the AHP and come up with strawman numbers for the AHP. He said the Study Team also needs to figure out how to constrain the missile mixes.

Mr. Murray mentioned the Army was doing portfolio reviews and there were too many precision pieces, which were wasting money.

Mr. Bressler said the SMEs for the CCMs would have to come up with the values. He suggested the values would change based on the person in command at the time and said the AHP could adapt. Mr. Bressler asked if the Army could send information about what is transpiring in the Army in regard to the missile portfolio.

Mr. Bressler said some casualties occurred due to weapon accidents. Mr. Murray said there have been some weapon accidents with the AT4. An armorer had been killed due to a faulty AT4 trigger; the weapon discharged while he was trying to get the trigger unstuck.

Mr. Murray mentioned the Army doctrine was way behind and it may take three to five years before some of the TTPs would be contained in doctrine.

The meeting concluded at approximately1130 hours.